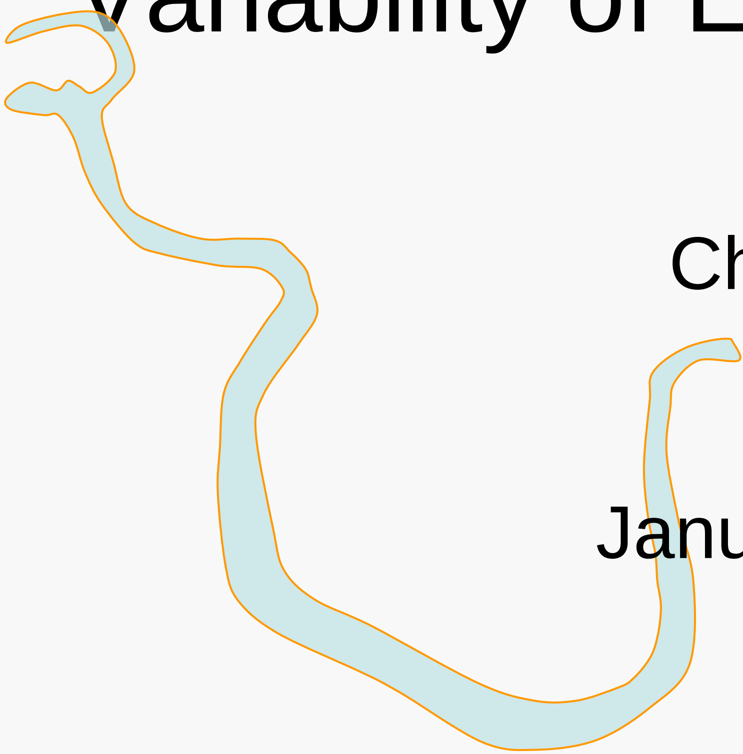
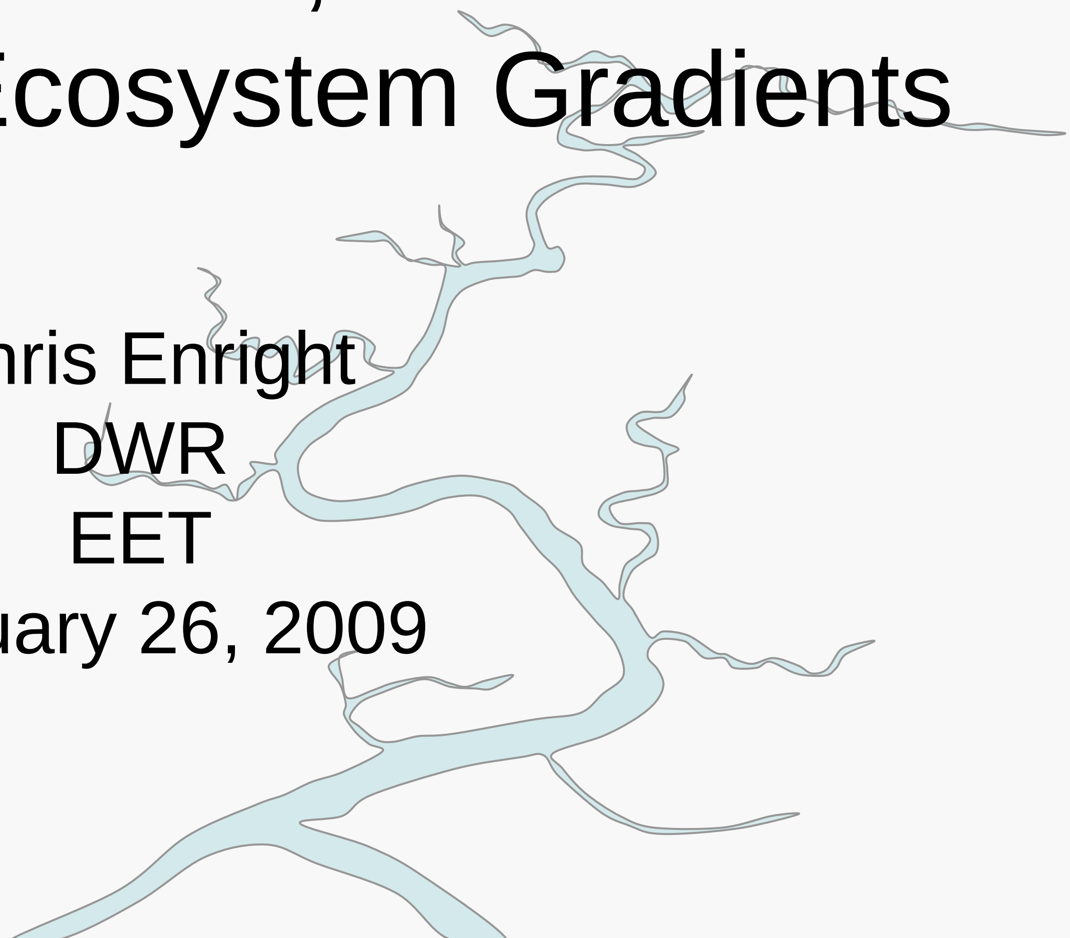
Tidal Slough "Geometry" Filters Estuarine Drivers, Mediates Transport Processes, and Controls Variability of Ecosystem Gradients





Chris Enright

DWR

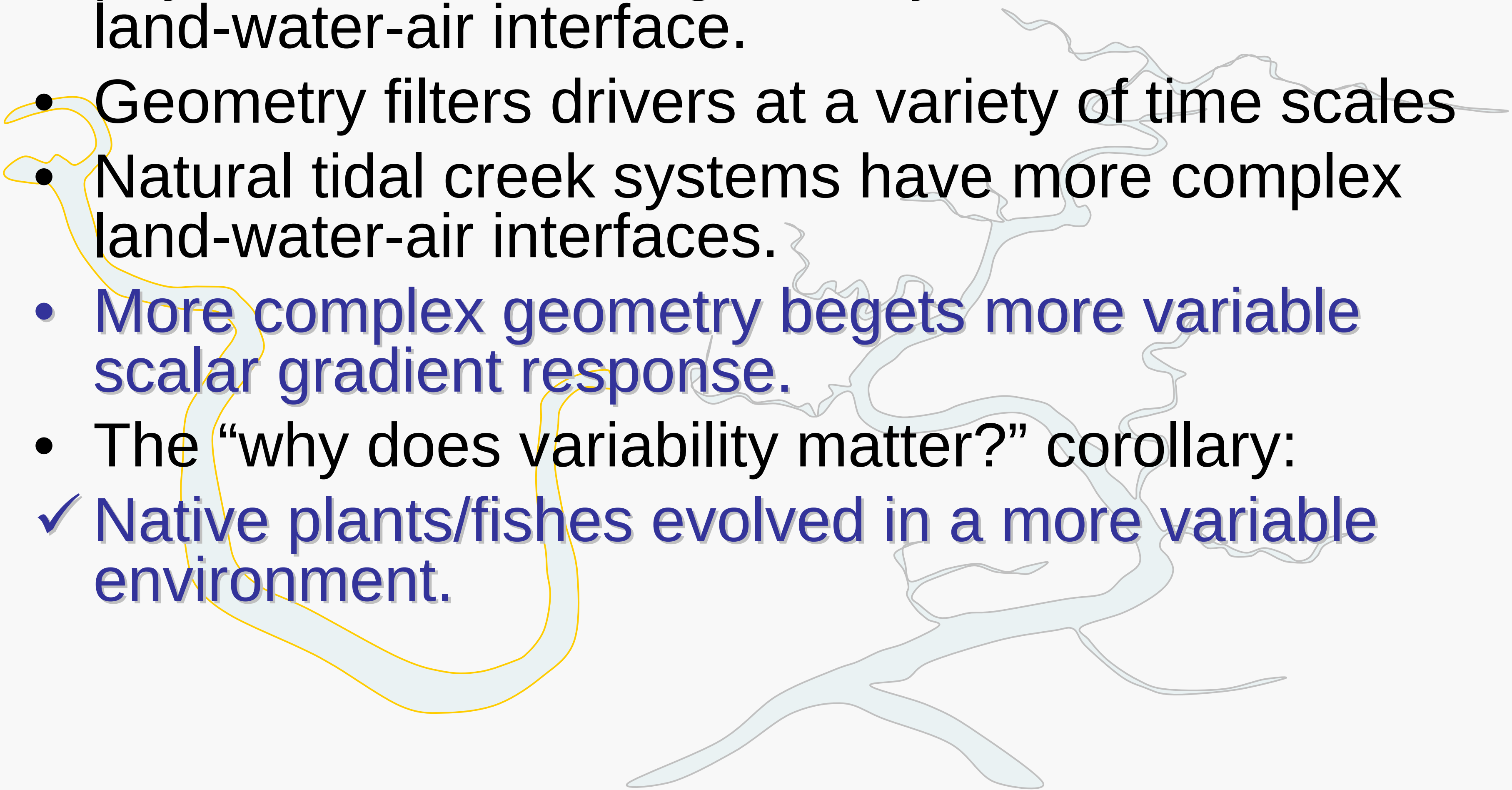
EET

January 26, 2009

Key ideas

- Estuaries generate <u>variability</u> by interaction of physical drivers and "geometry as filter" at the land-water-air interface.
- Geometry filters drivers at a variety of time scales
- Natural tidal creek systems have more complex land-water-air interfaces.
- More complex geometry begets more variable scalar gradient response.
- The "why does variability matter?" corollary:

✓ Native plants/fishes evolved in a more variable environment.



Variability is stressful!

For example, consider that tides both stress and favor aquatic versus terrestrial biota.

- Low tide, hot day stresses fish/inverts while stimulating photosynthesis.
- High tide stresses rooted plants and reduces gas exchange and light.
- Nevertheless, **this is the native species template.**

DRERIP Hydrodynamics Conceptual Model:

Geometry "filters" estuarine drivers

Drivers
(forcing mechanisms)

- Meteorology
- Tides
- River inputs

Linkages
(hydrodynamic processes)

- Advection
- Dispersion
- Gravitational Circulation

Outcomes
(Chemical/Biological Habitat Characteristics)

Gradients of
- Residence time
- Salinity
- Temperature
- Sediment
- Biota
- Toxics
- etc.

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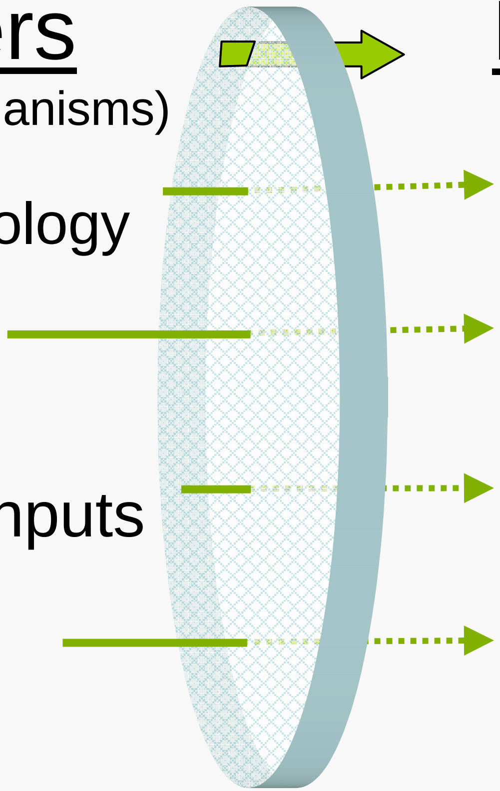
Geometry “filters” estuarine drivers

Geometry
(Like a Filter)



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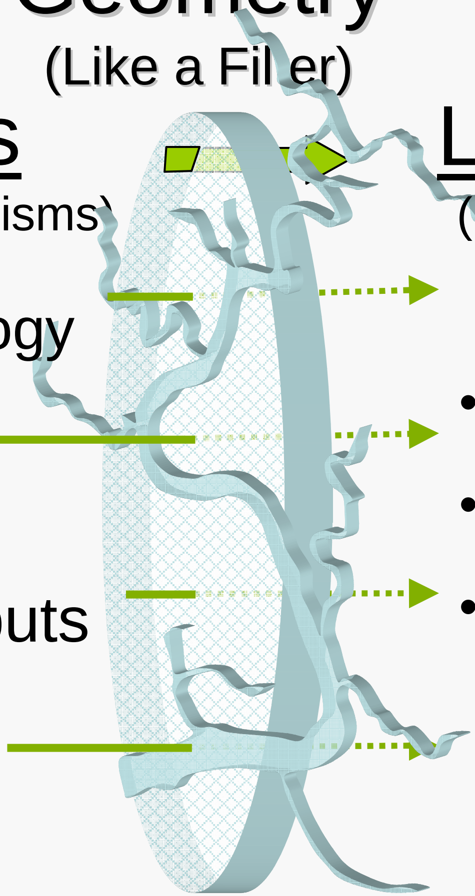

First Mallard Branch

Linkages
(hydrodynamic processes)

- Advection
- Dispersion
- Gravitational Circulation

Outcomes
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- Residence time
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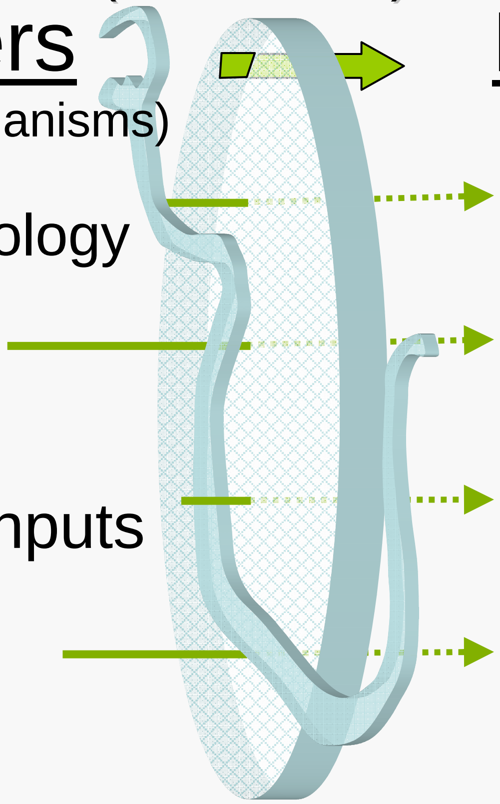
DRERIP Hydrodynamics Conceptual Model:

Geometry “filters” estuarine drivers

Geometry

(Like a Filter)



Sheldrake Slough

Drivers

(forcing mechanisms)

- Meteorology
- Tides
- River inputs

Linkages

(hydrodynamic processes)

- Advection
- Dispersion
- Gravitational Circulation

Outcomes

(Chemical/Biological Habitat Characteristics)

Gradients of

- Residence time
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- etc.

What do we mean by “variability?”

- Concentration gradients in space and time (“<u>O</u>utcomes”).

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- Concentration gradients in space and time ("<u>O</u>utcomes").
- Space and time: must consider <u>scale</u> because drivers oscillate and episode at different scales

What do we mean by “variability?”

- Drivers of variability in *time* (dC/dt):

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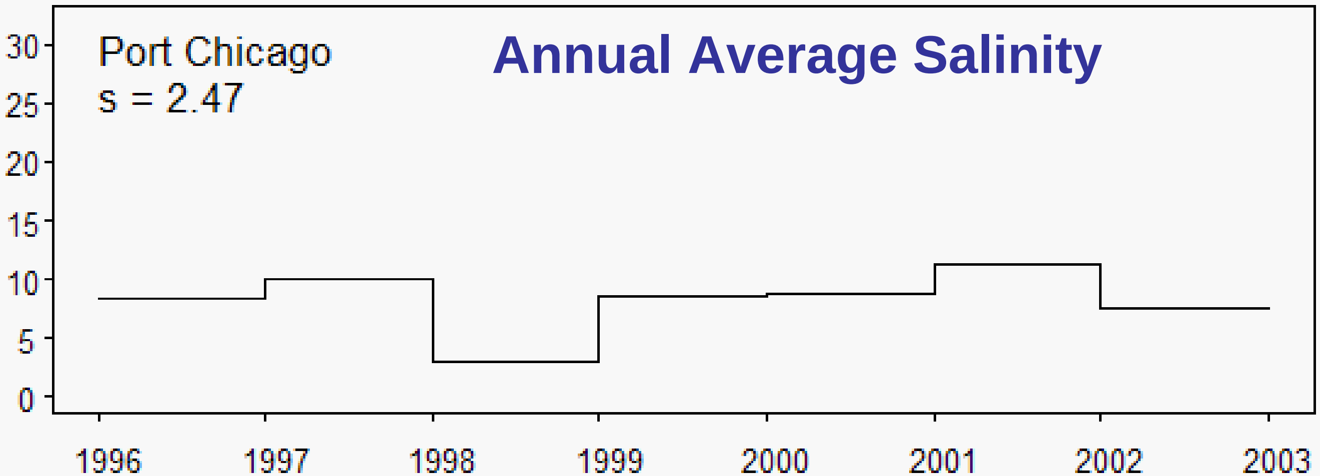
- Drivers of variability in *time* (dC/dt):

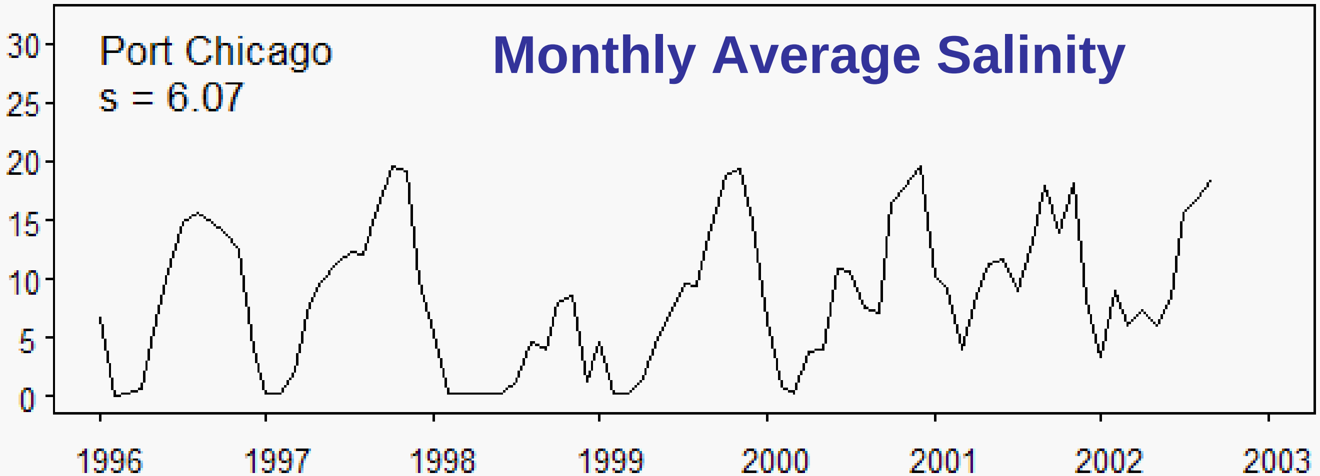


DRIVERS:

1. ENSO status
2. Delta Outflow

What do we mean by “variability?”

- Drivers of variability in *time* (dC/dt):

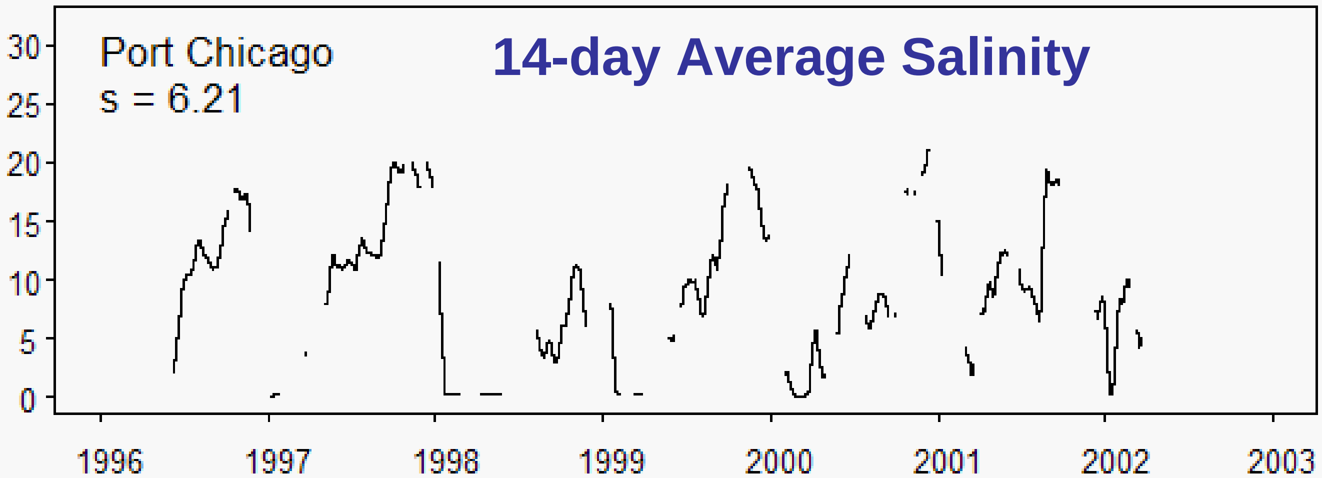


DRIVERS:

1. Delta Outflow
2. Seasonal climat
3. ENSO Status

What do we mean by “variability?”

- Drivers of variability in *time* (dC/dt):

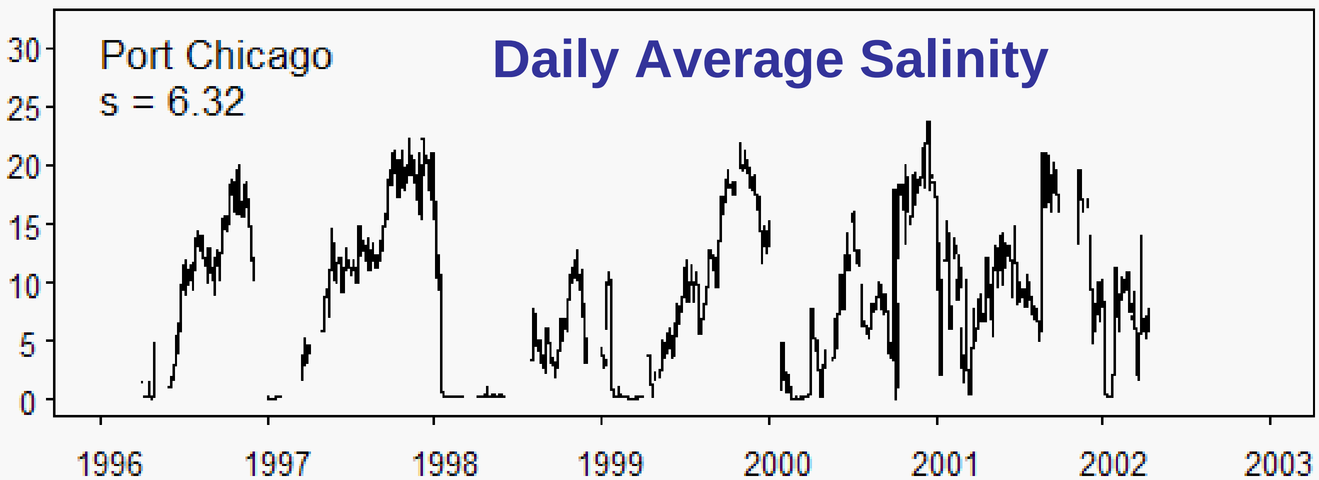


DRIVERS:

1. Spring-Neap
2. Delta Outflow
3. Semi-drnl Tide

What do we mean by "variability?"

- Drivers of variability in *time* (dC/dt):

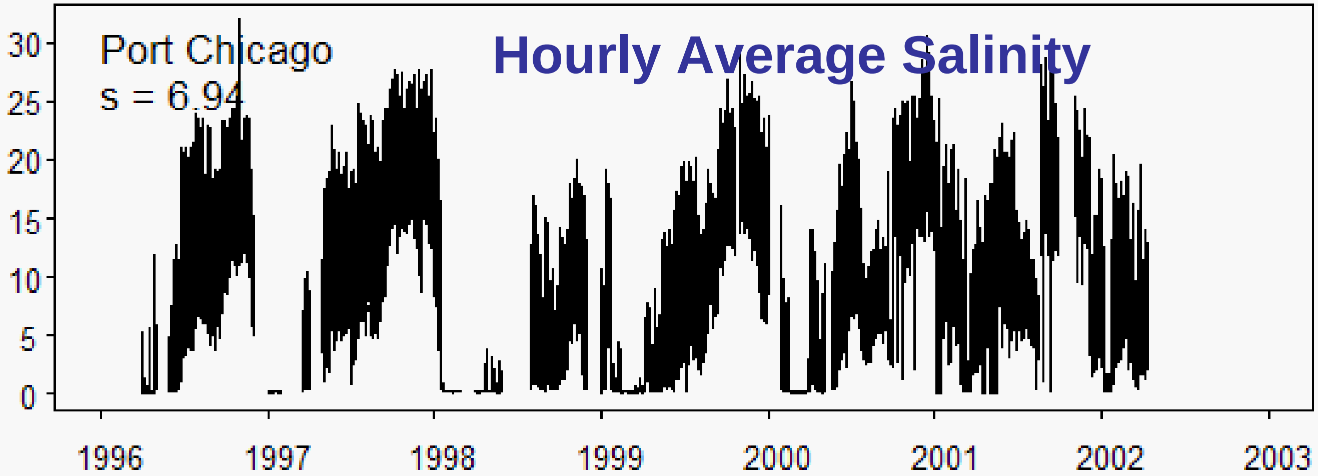


DRIVERS:

1. Semi-drnl tide
2. Delta outflow
3. Wind
4. Bar. pressure

What do we mean by “variability?”

- Drivers of variability in *time* (dC/dt):



DRIVERS:

1. Wind
2. Semi-drnl Tide
3. Outflow

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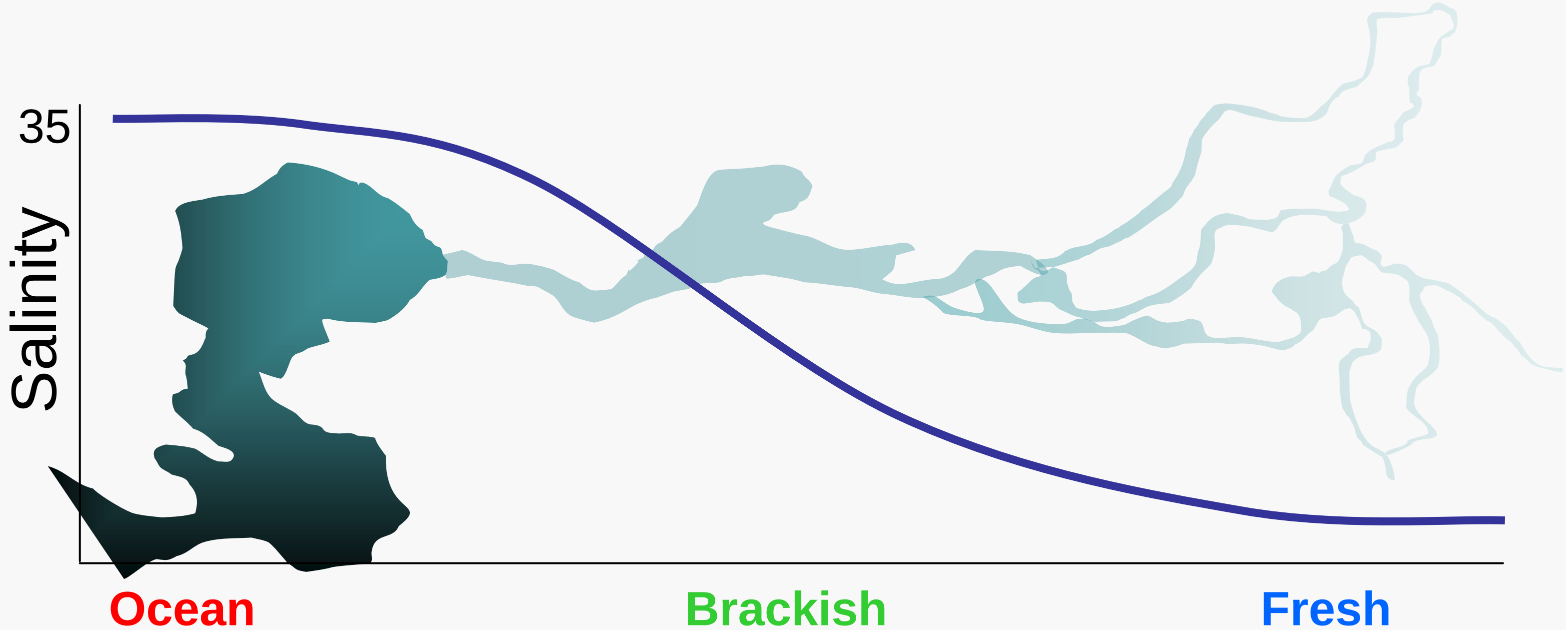

DISPERSION of salt upstream **=** **ADVECTION** of salt downstream

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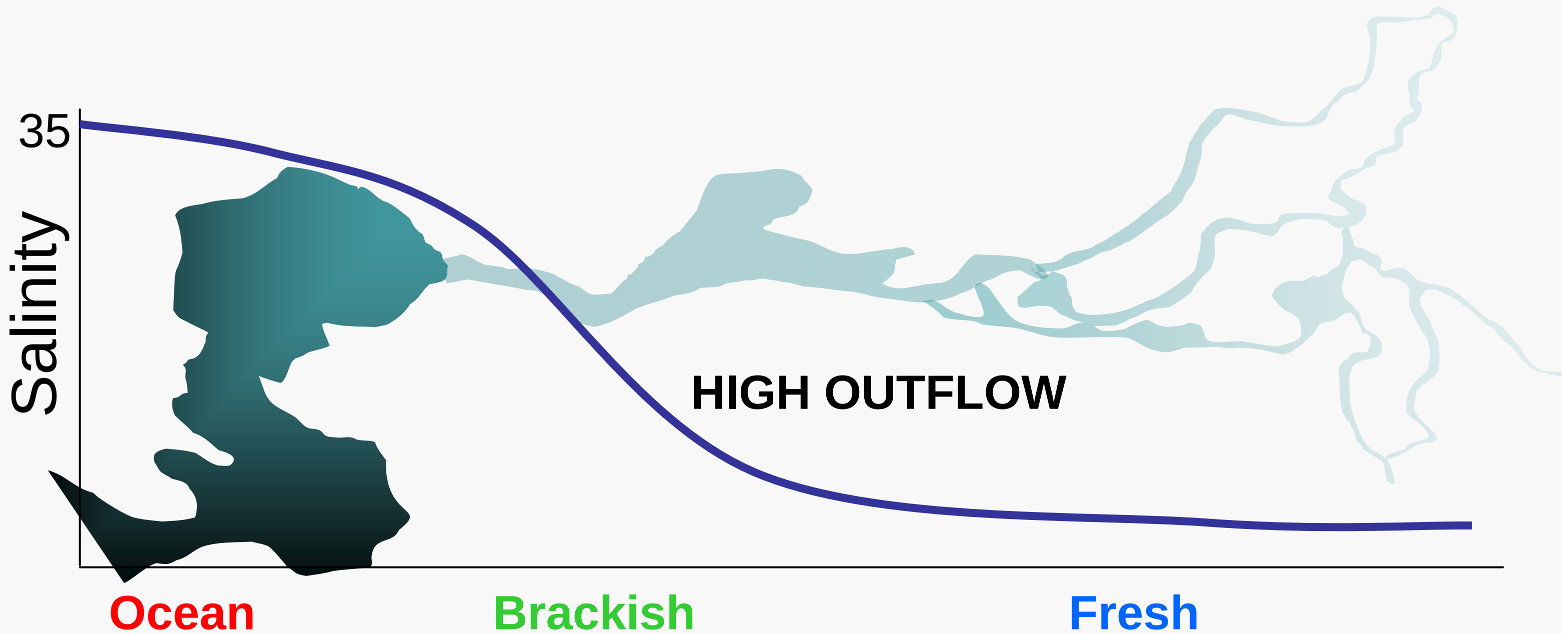

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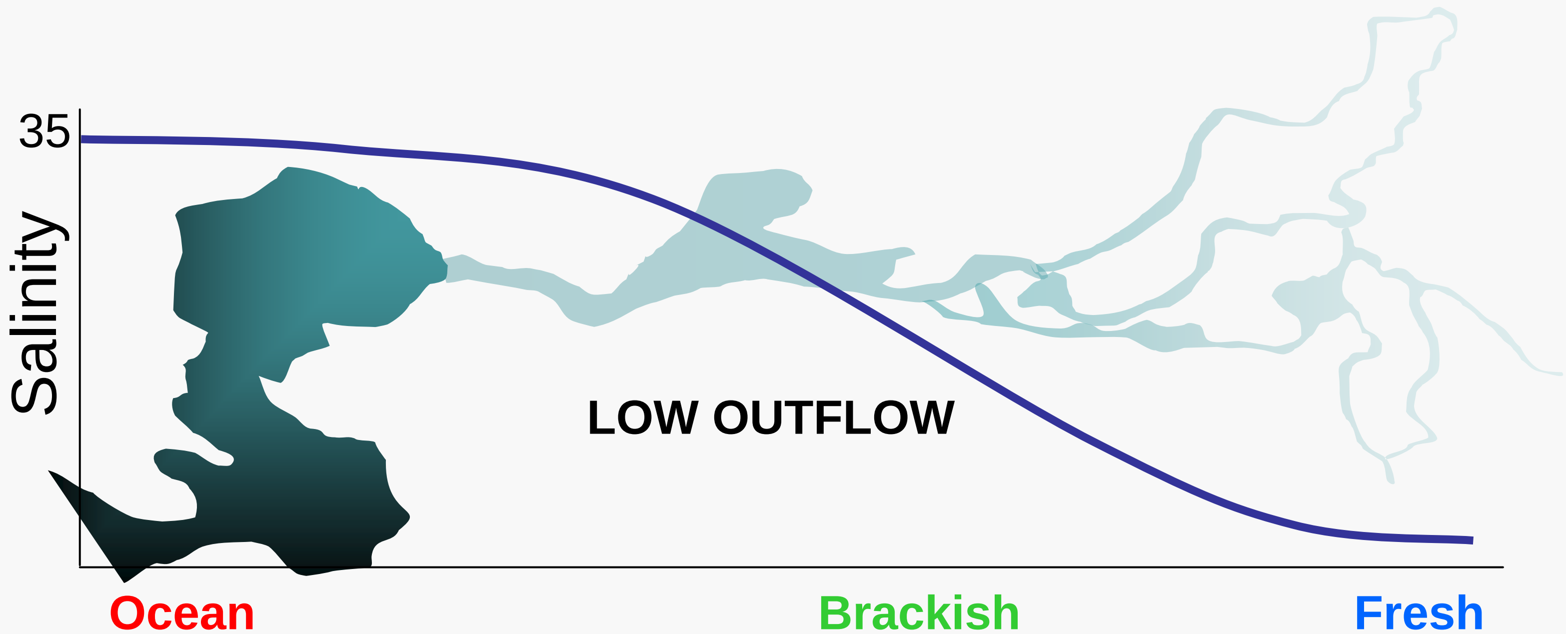
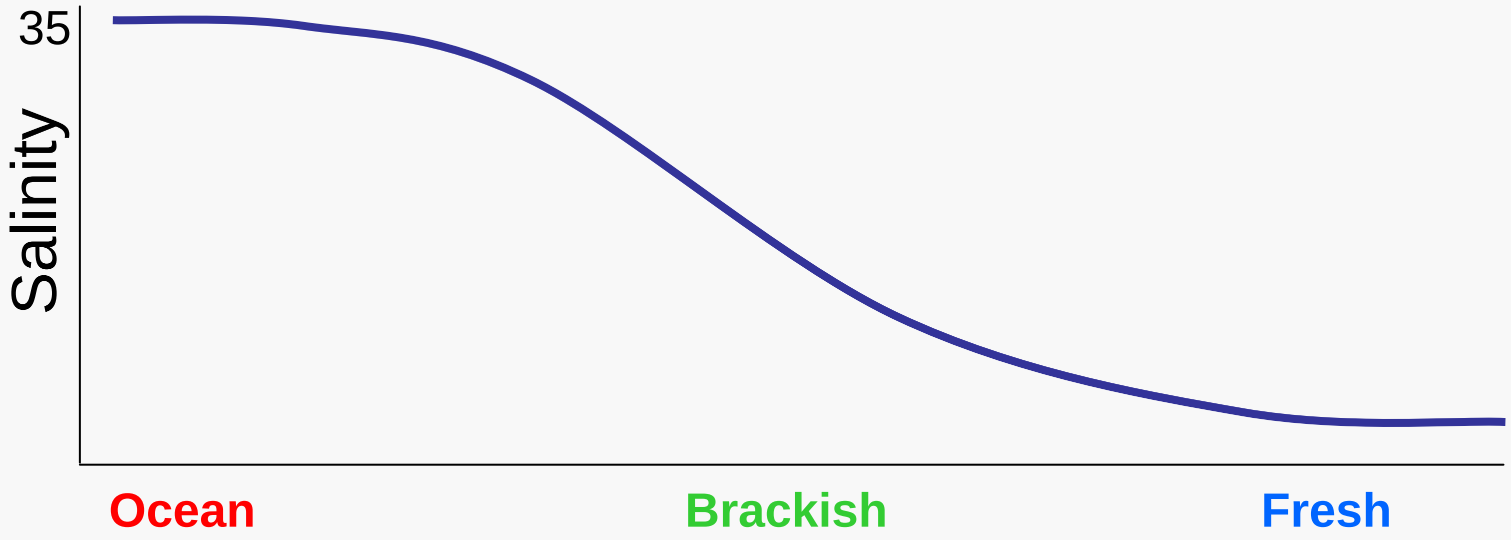


DISPERSION of salt upstream = **ADVECTION** of salt downstream

The salt balance also depends on



DISPERSION of salt upstream **=** **ADVECTION** of salt downstream

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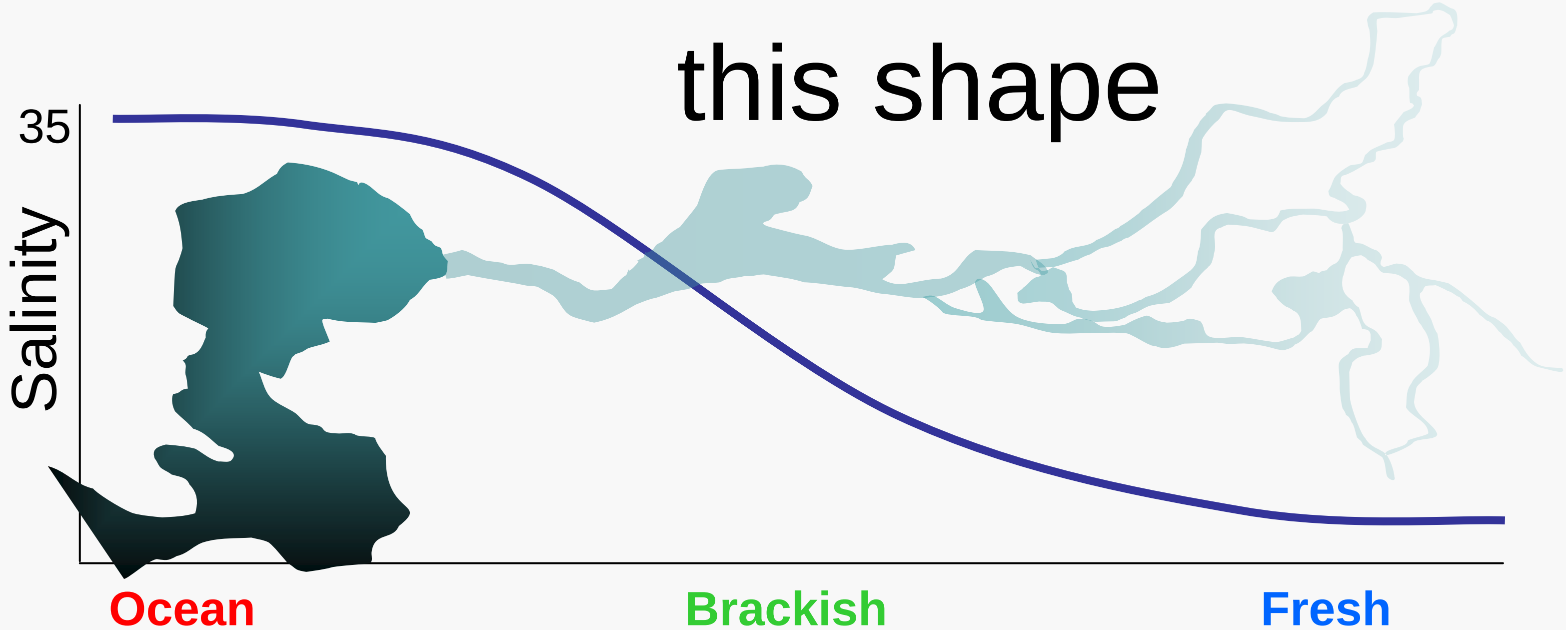
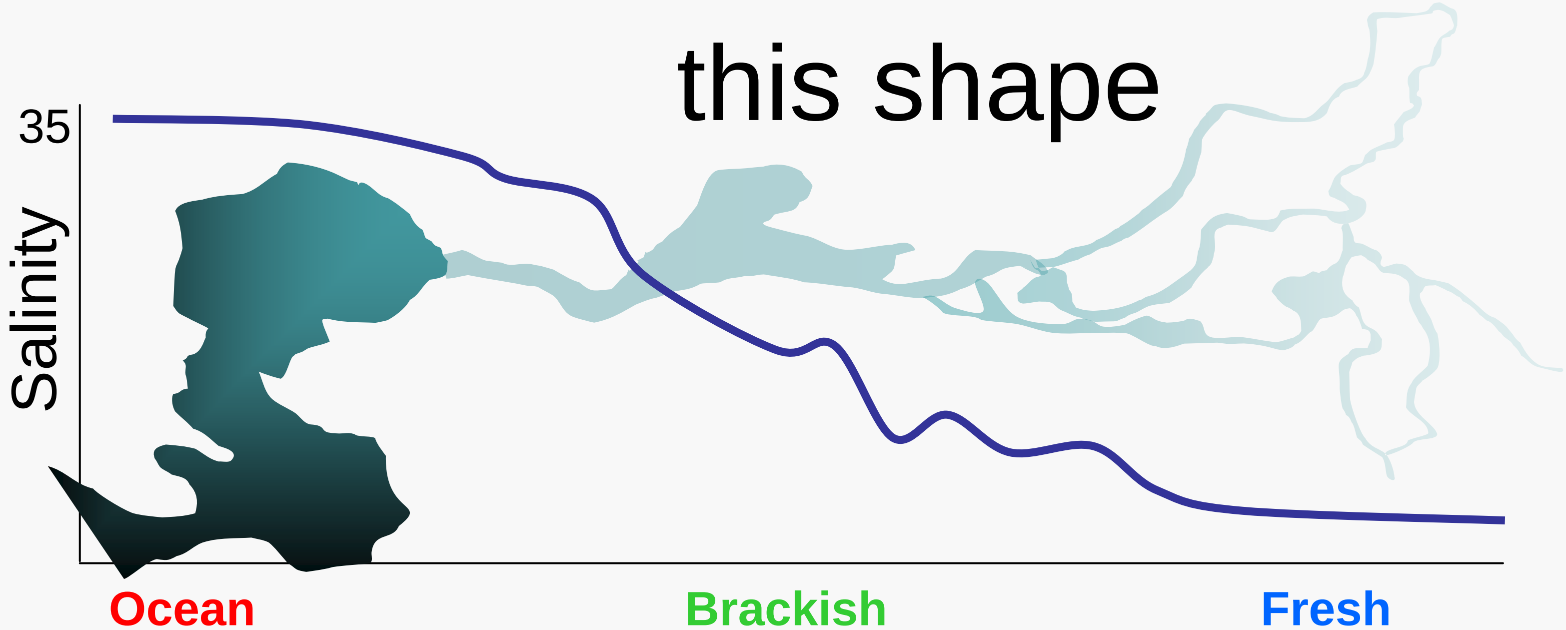


DISPERSION of salt upstream **=** **ADVECTION** of salt downstream

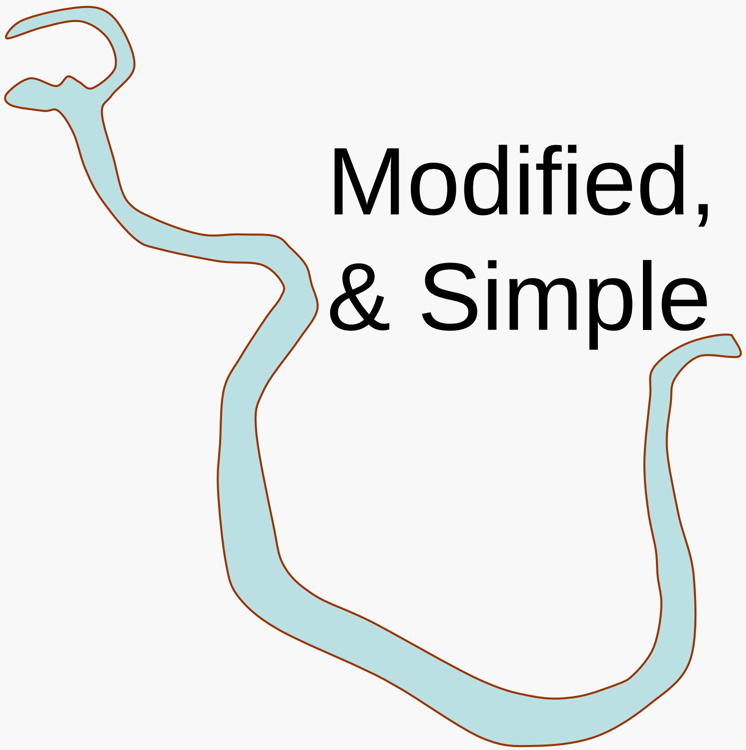
The salt balance also depends on

this shape



DISPERSION of salt upstream = **ADVECTION** of salt downstream

Scaling down, geometry really matters

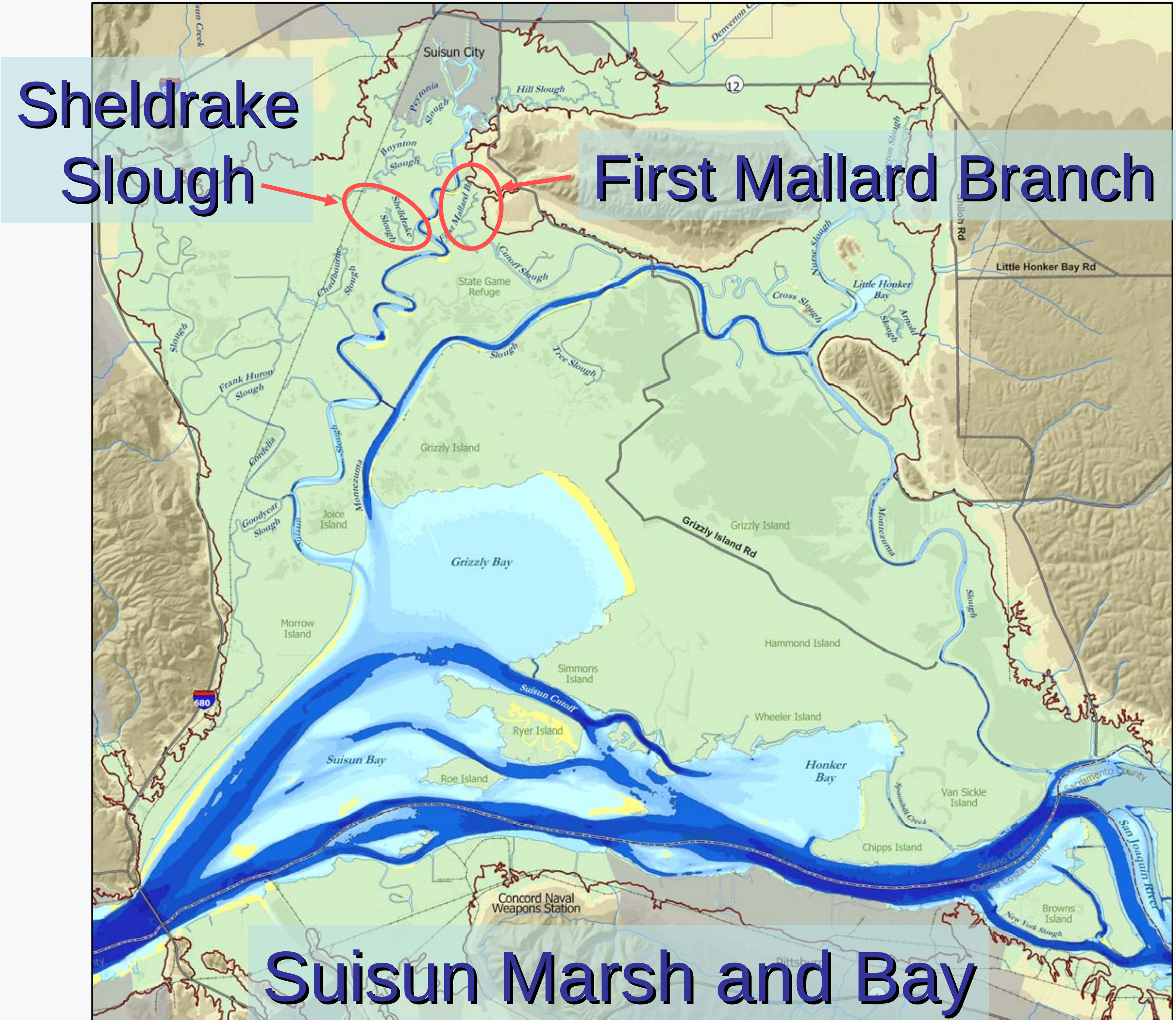


Modified,
& Simple

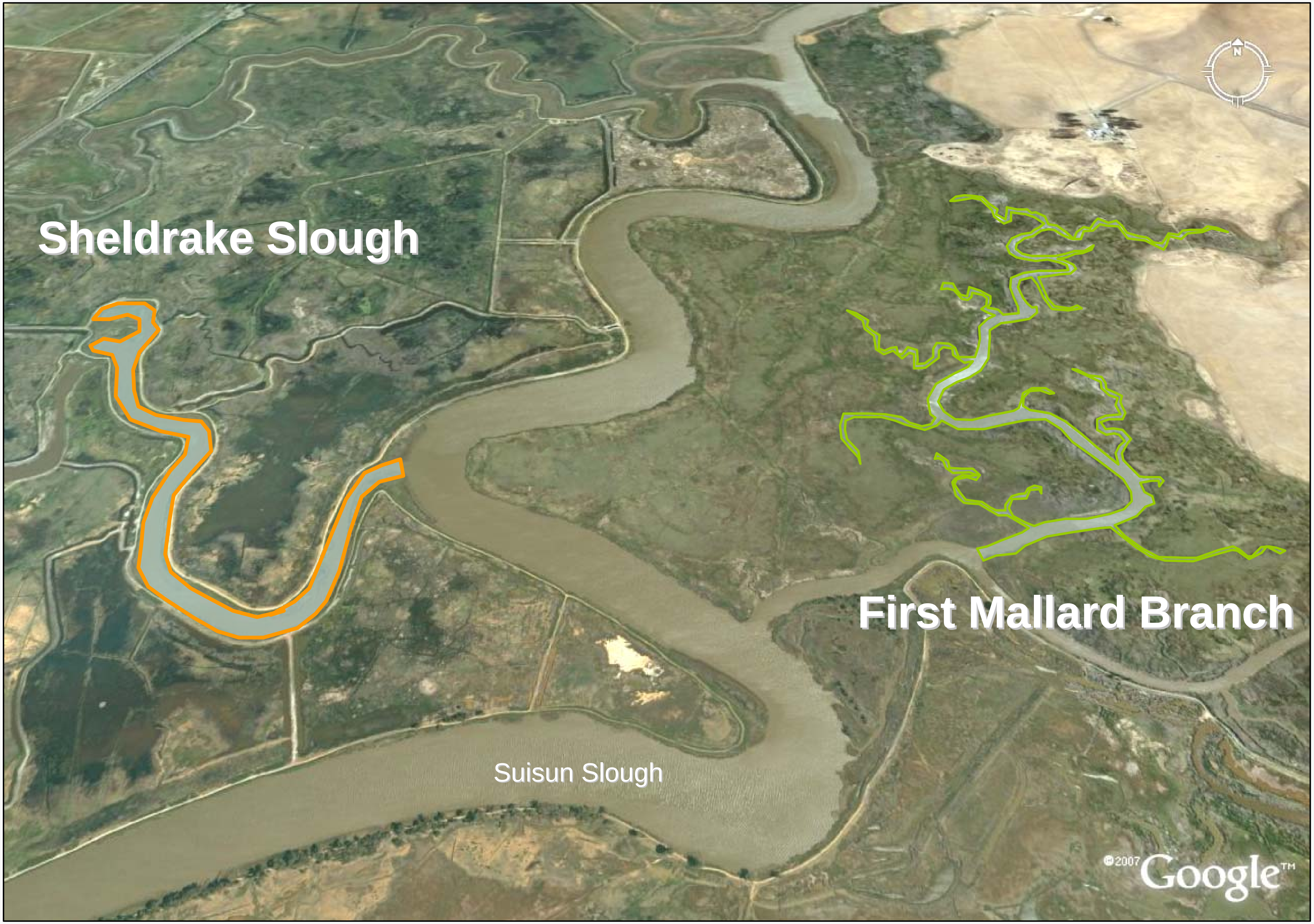
Sheldrake Slough

~Natural,
& Complex

First Mallard Branch


Sheldrake Slough
First Mallard Branch
Suisun Marsh and Bay
Suisun City
Peytonia Slough
Boynton Slough
Sheldrake Slough
First Mallard Br.
Hill Slough
Cutoff Slough
State Game Refuge
Chadbourne Slough
Frank Huron Slough
Cordelia Slough
Goodyear Slough
Suisun Slough
Montezuma Slough
Joice Island
Grizzly Island
Grizzly Bay
Tree Slough
Nurse Slough
Cross Slough
Little Honker Bay
Arnold Slough
Little Honker Bay Rd
Shiloh Rd
Grizzly Island Rd
Morrow Island
Hammond Island
Simmons Island
Suisun Cutoff
Wheeler Island
Ryer Island
Suisun Bay
Roe Island
Honker Bay
Van Sickle Island
Spoonbill Creek
Chipps Island
Concord Naval Weapons Station
Browns Island
New York Slough
San Joaquin River
Sacramento County
Solano County
Contra Costa County
12
680

Different Physiography and Land-Water Interface



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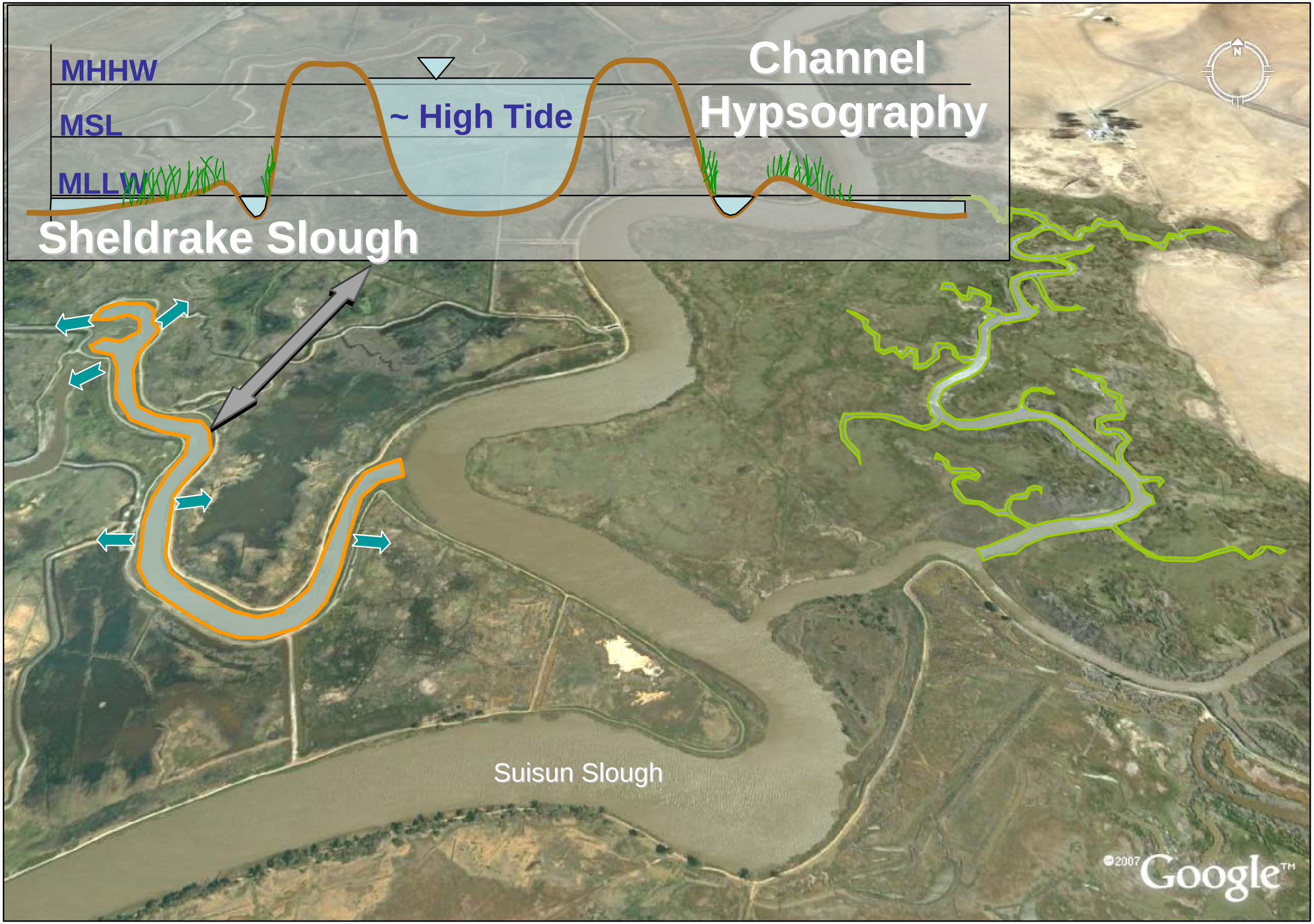

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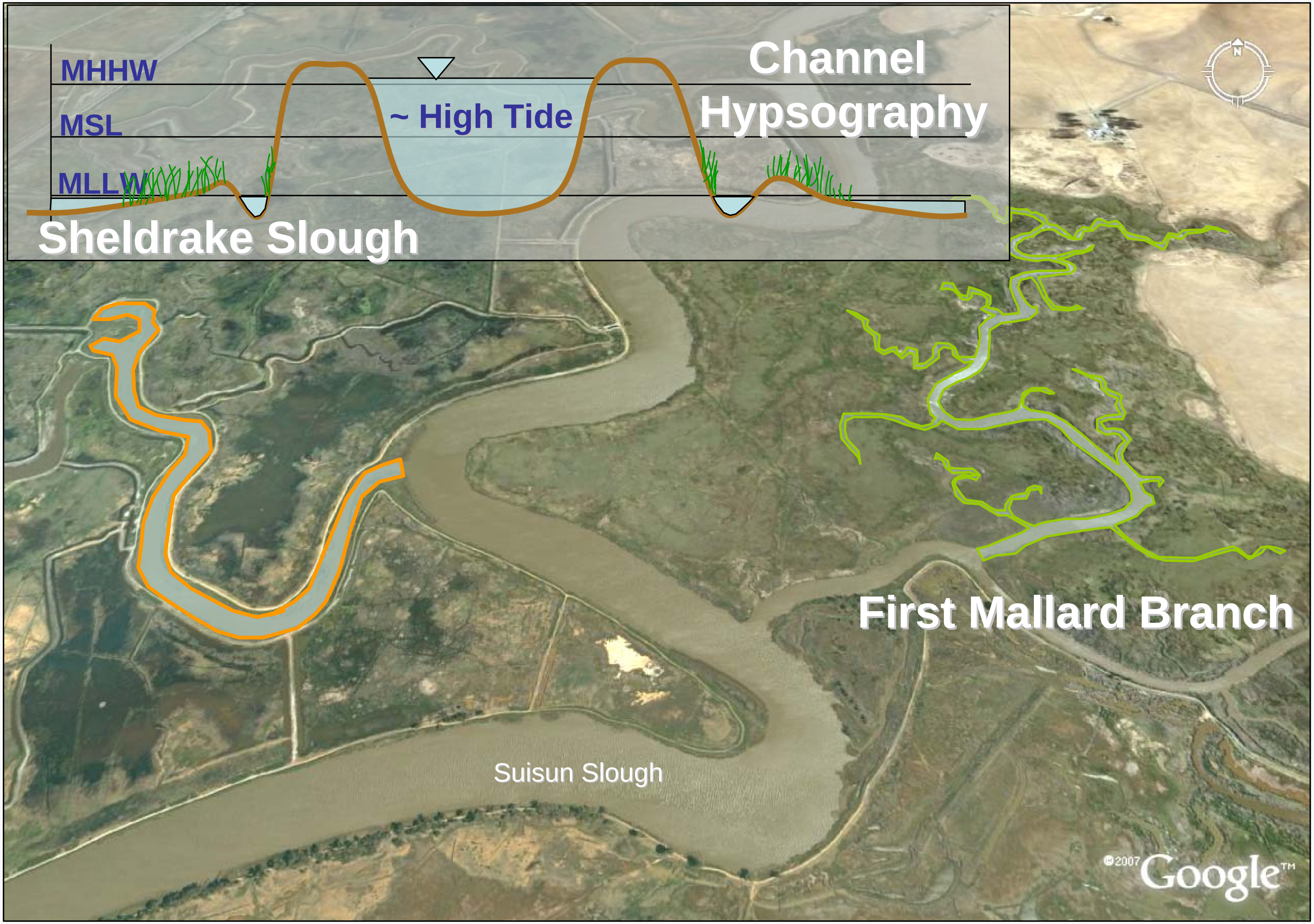

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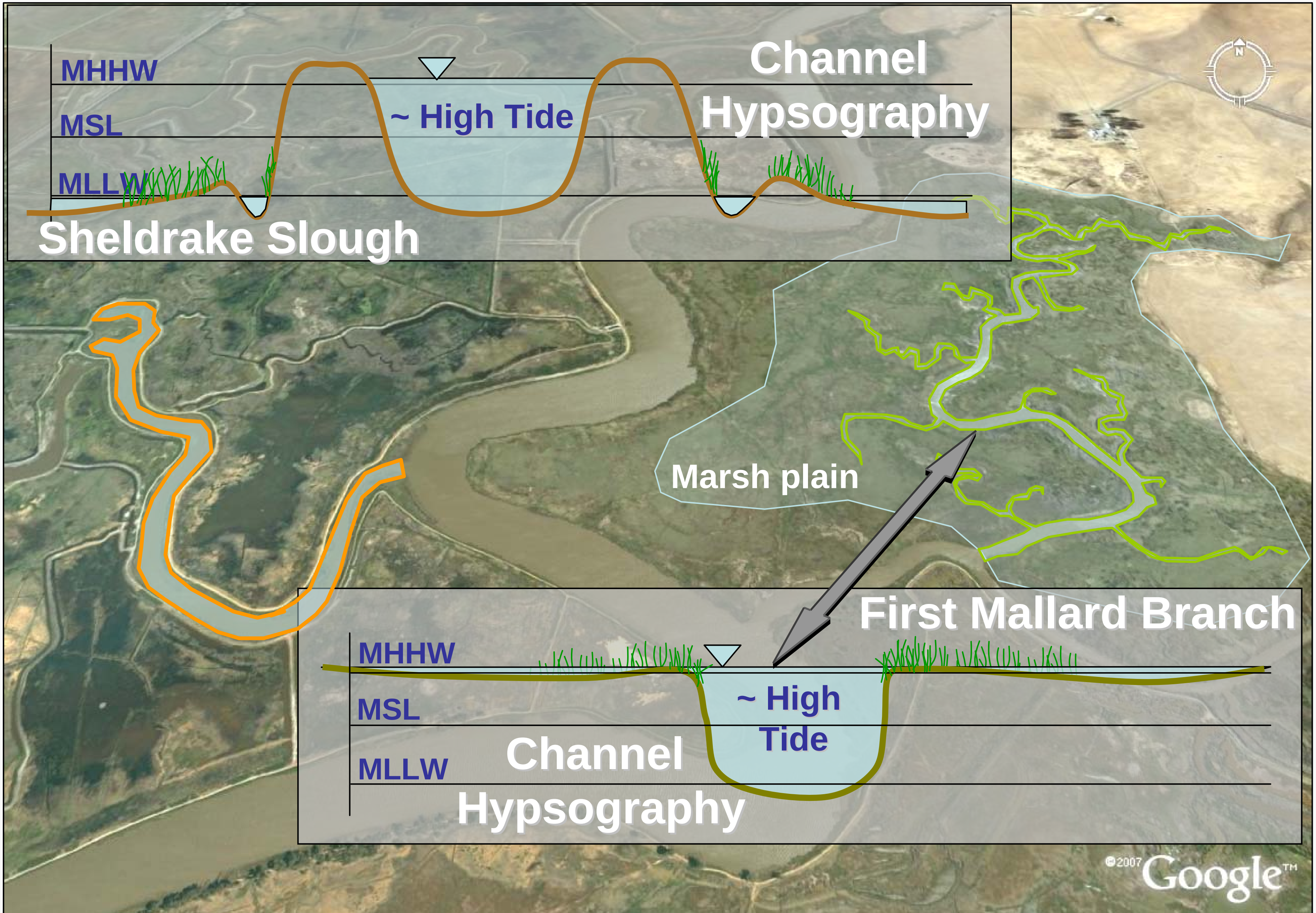
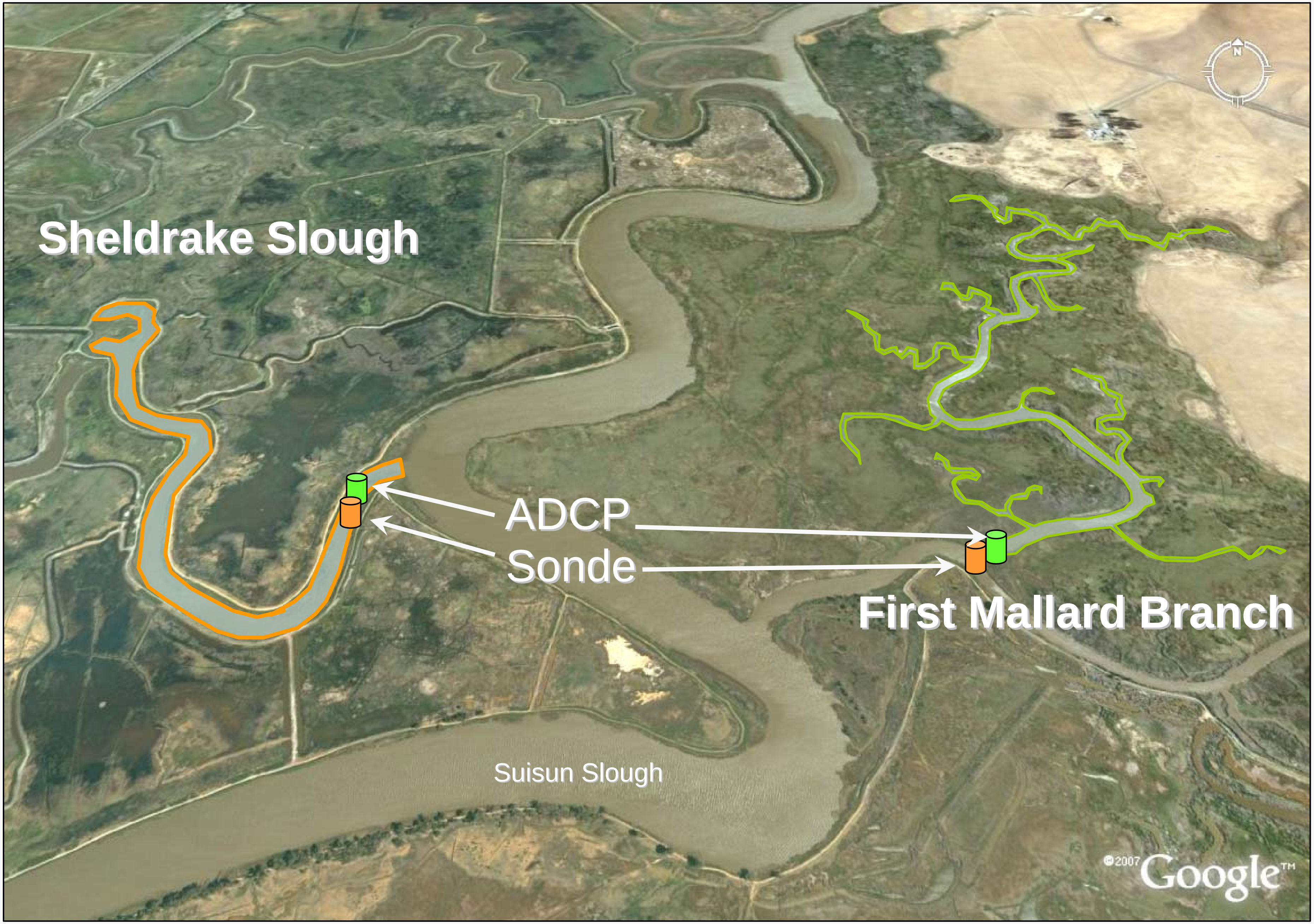
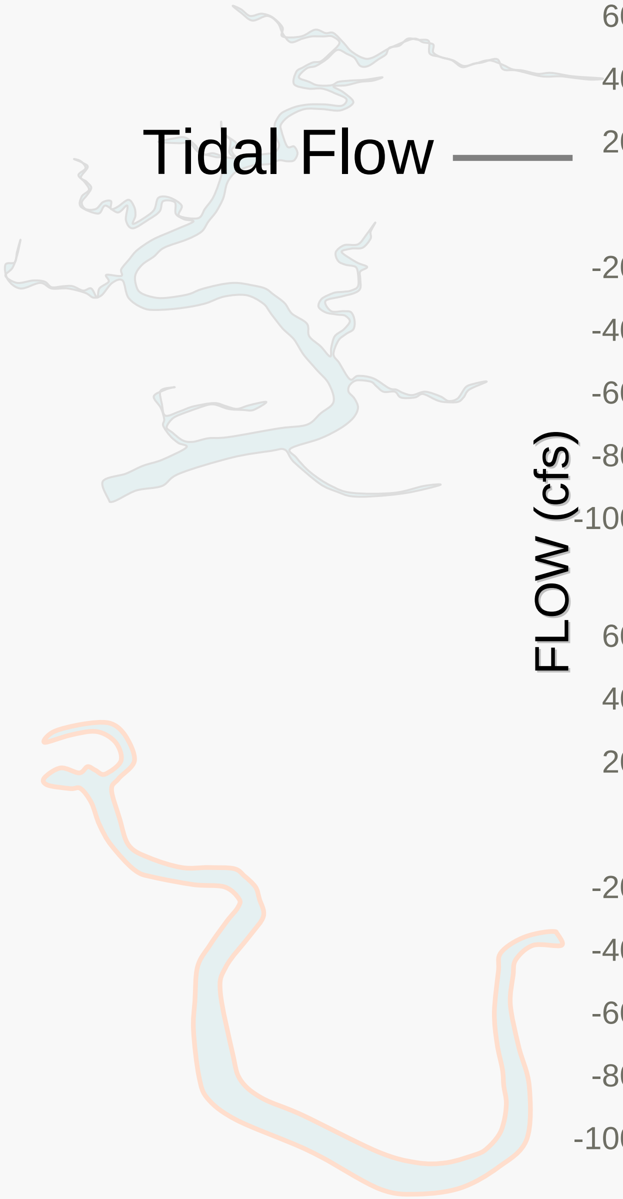
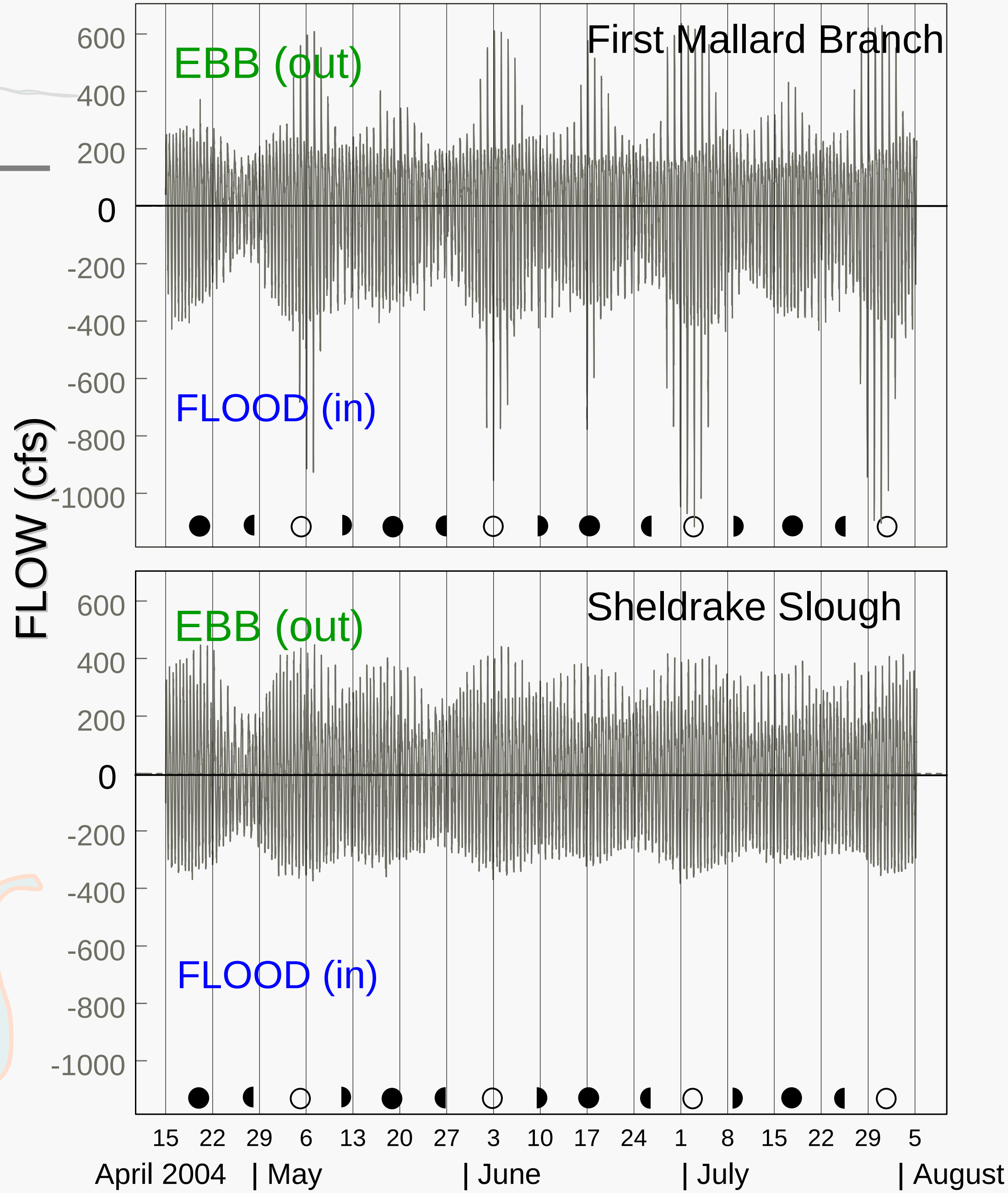


Different Physiography and Land-Water Interface

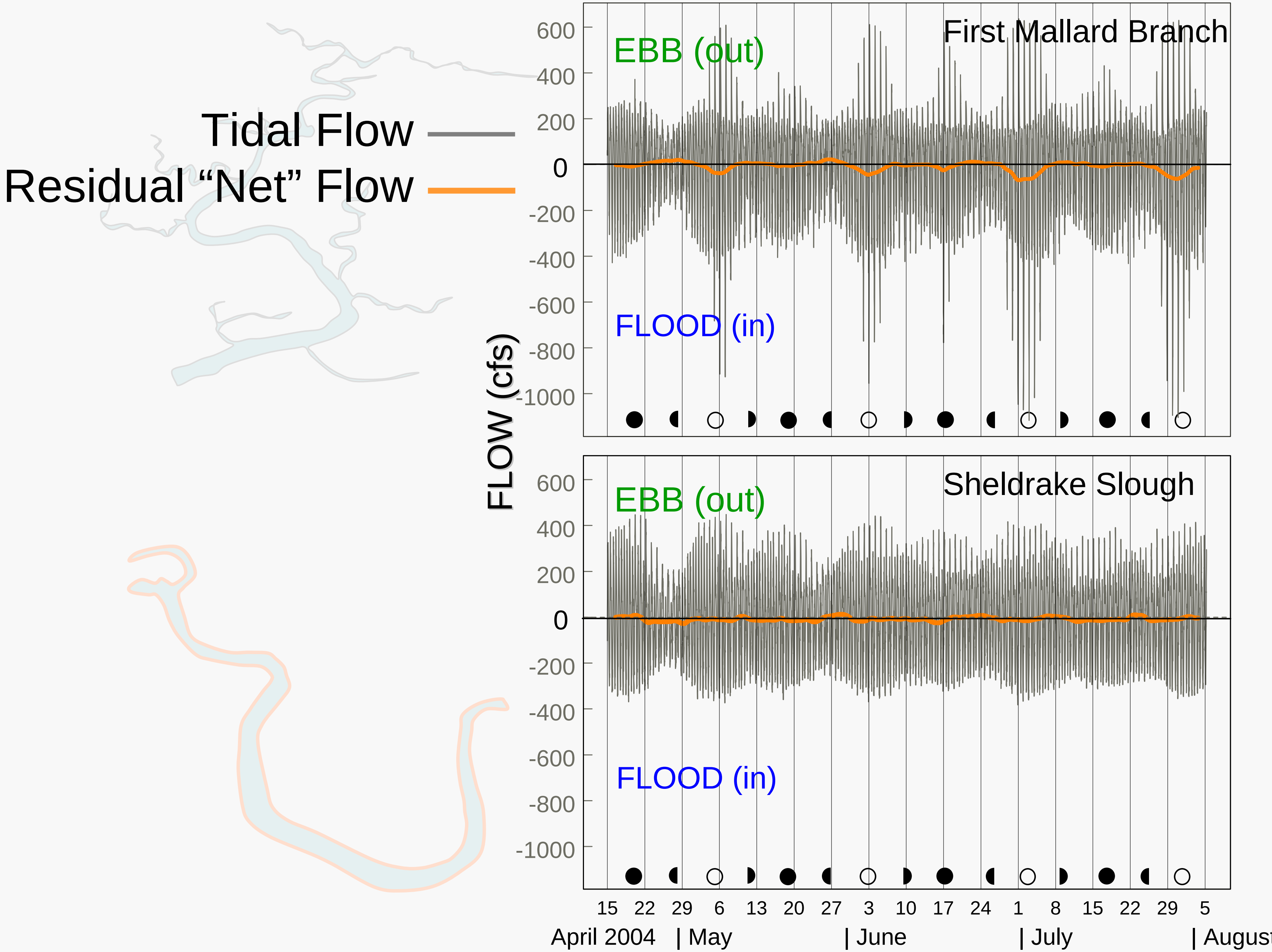


Tidal Flow

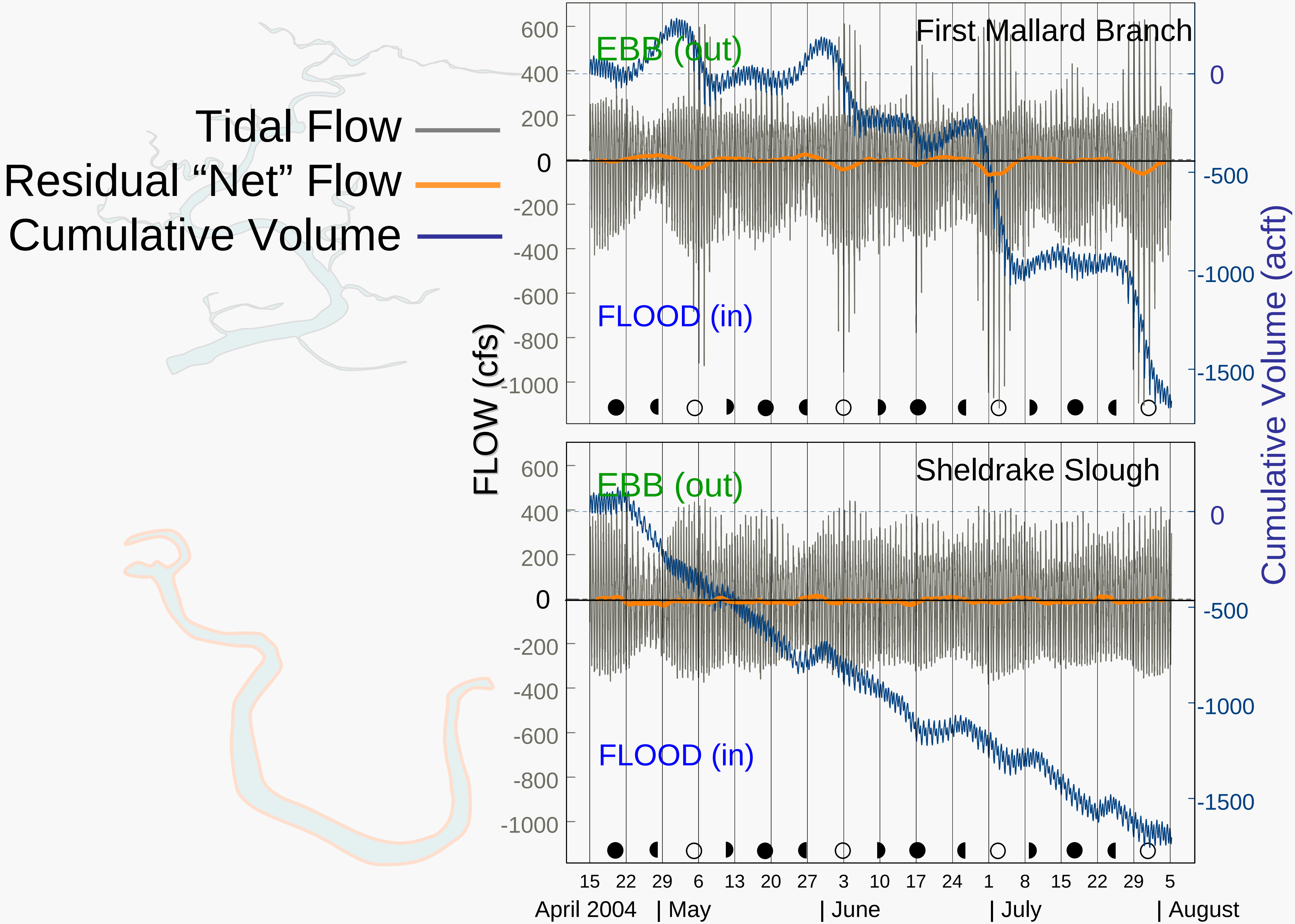

Tidal Flow


First Mallard Branch
EBB (out)
FLOOD (in)
Sheldrake Slough
EBB (out)
FLOOD (in)
FLOW (cfs)
600
400
200
0
-200
-400
-600
-800
-1000
15
22
29
6
13
20
27
3
10
17
24
1
8
15
22
29
5
April 2004
| May
| June
| July
| August

Tidal and Net Flow



Tidal/Net Flow and Cumulative Volume



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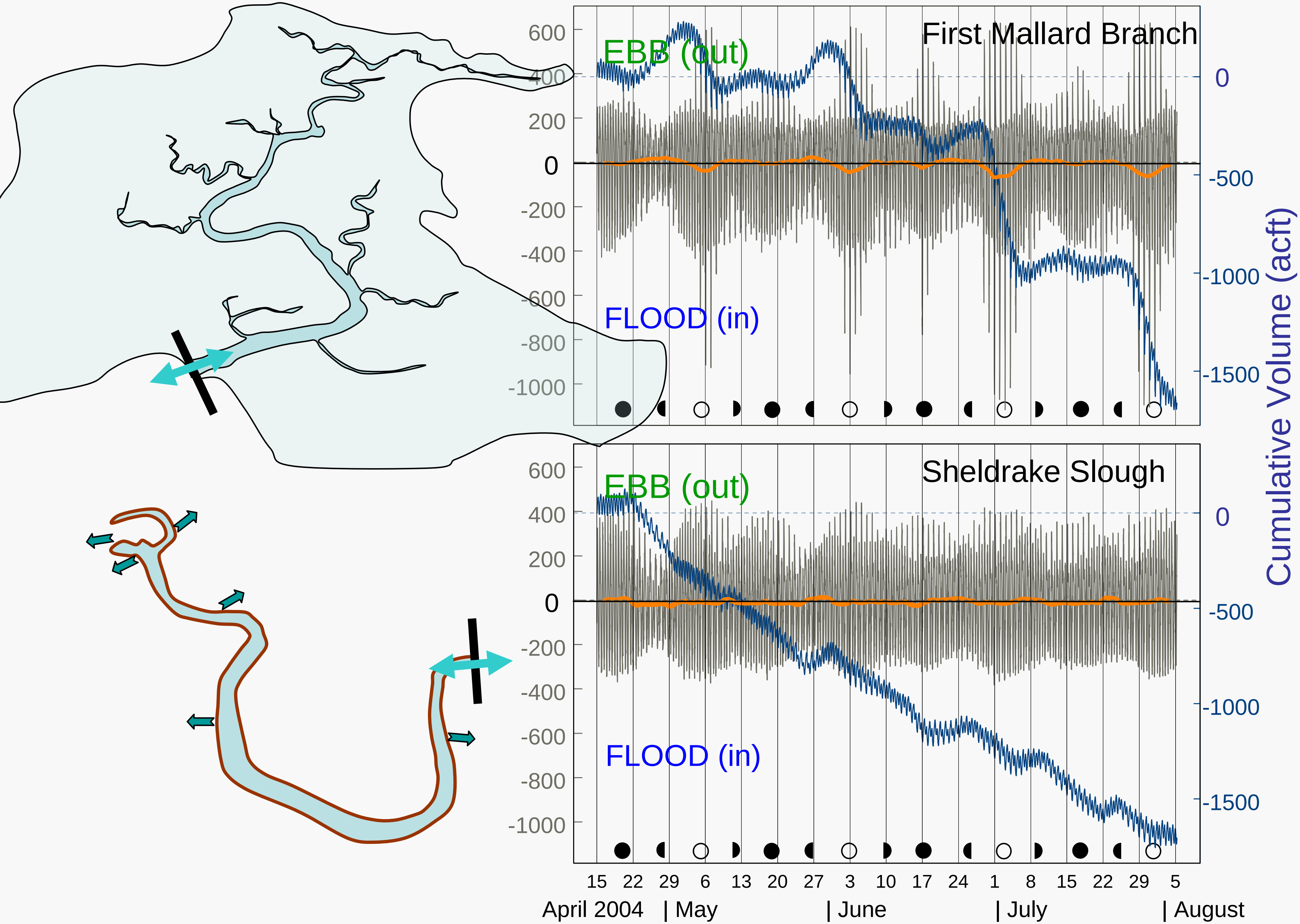

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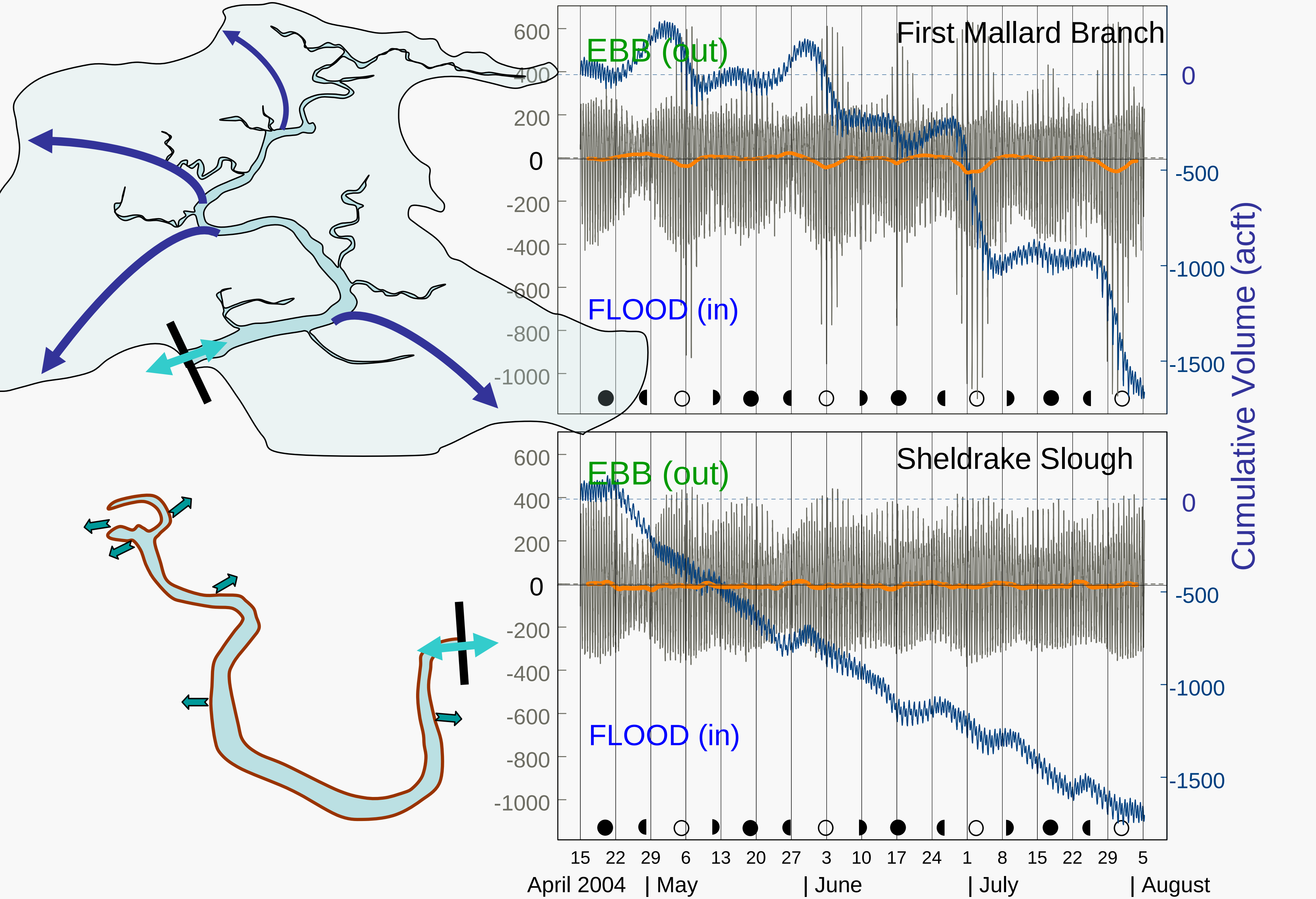
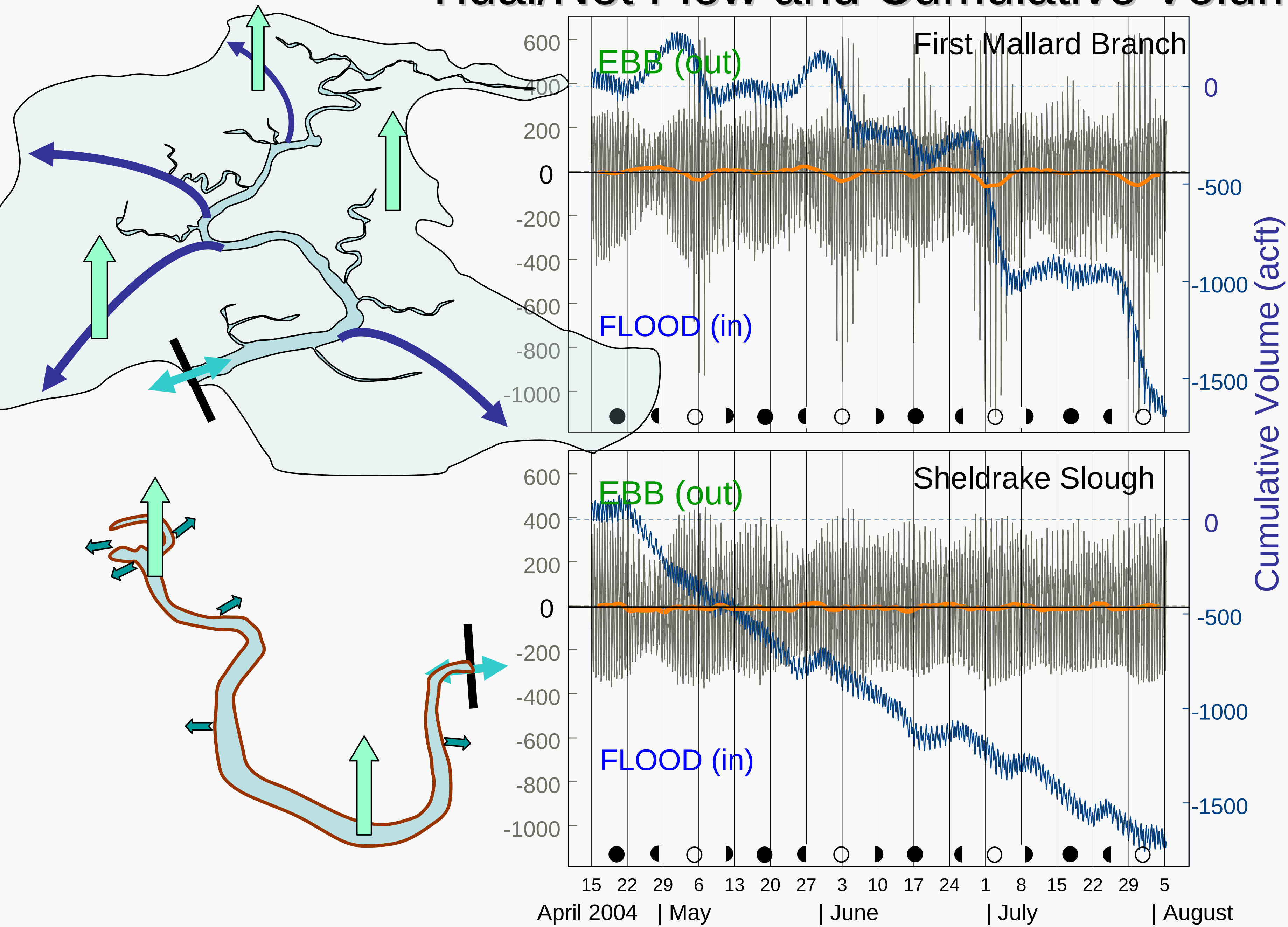
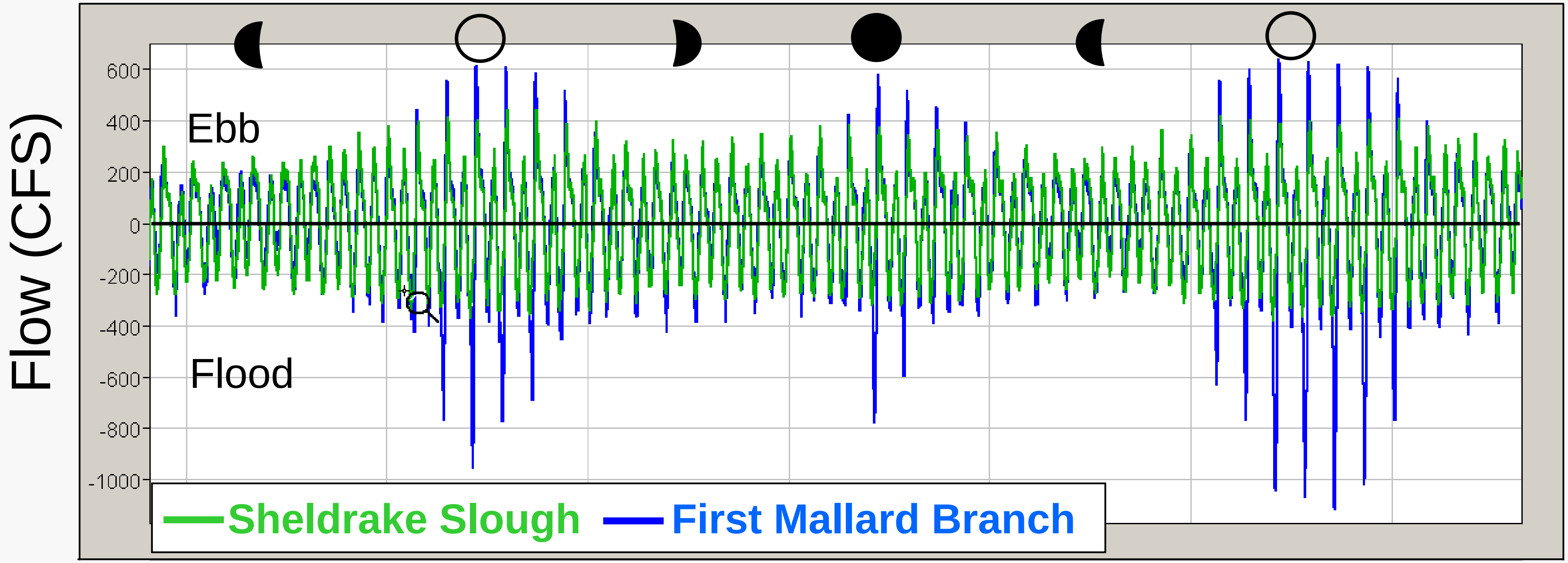



photo by Rob Schroeter
First Mallard Branch Marsh Plain
Suisun Slough

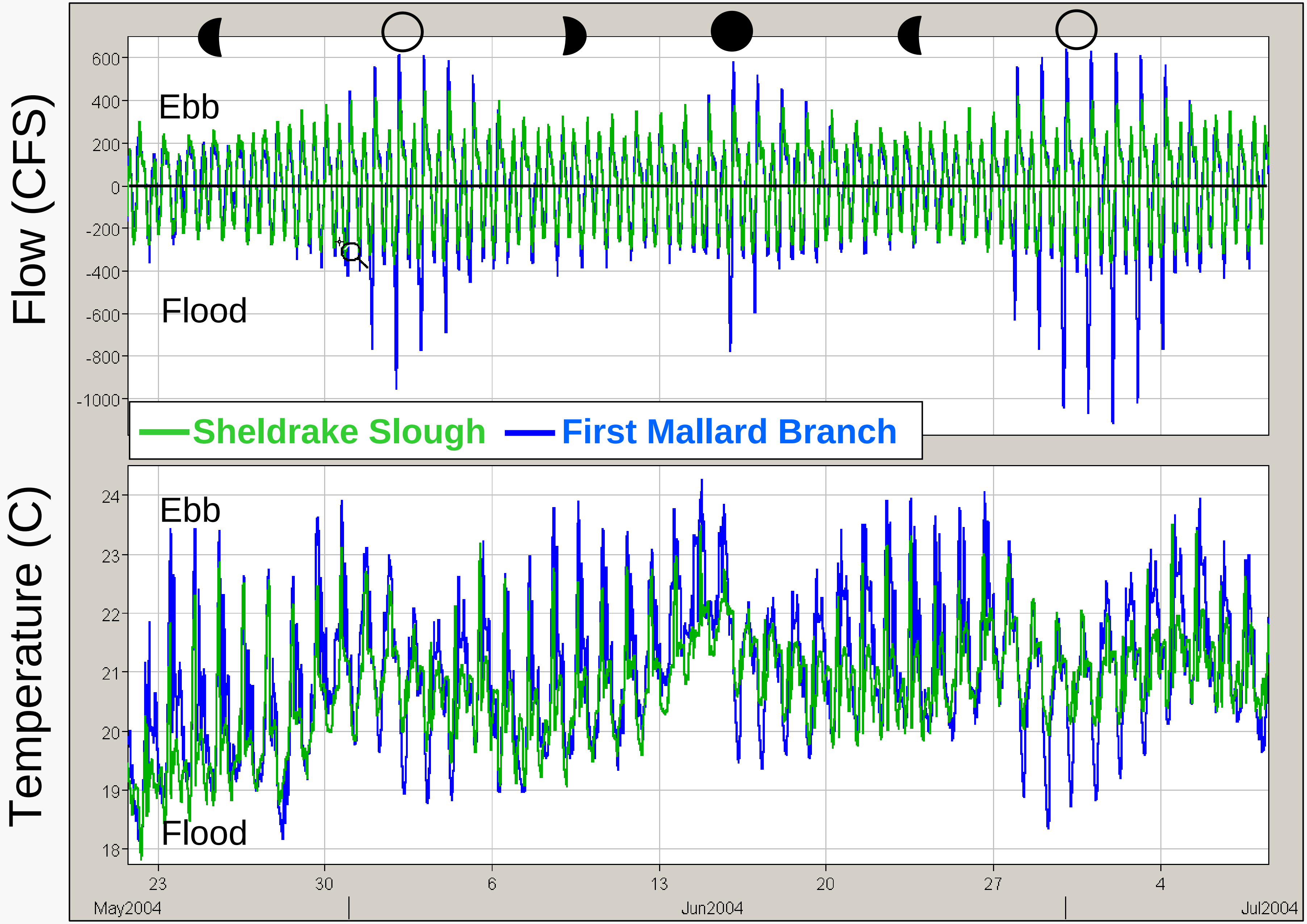
Tidal/Net Flow and Cumulative Volume



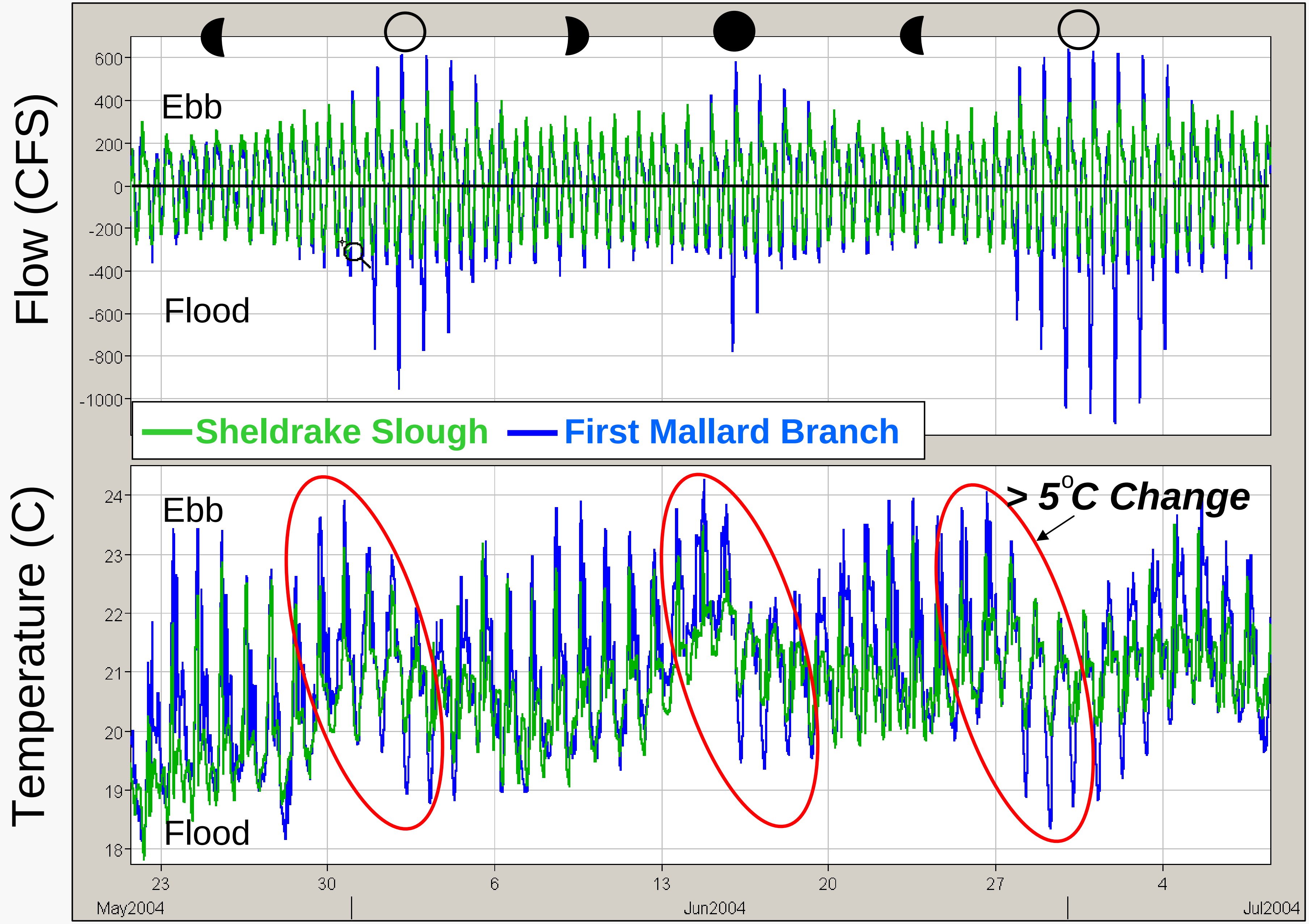
Flow Variability



Flow and Temperature Variability



Flow and Temperature Variability



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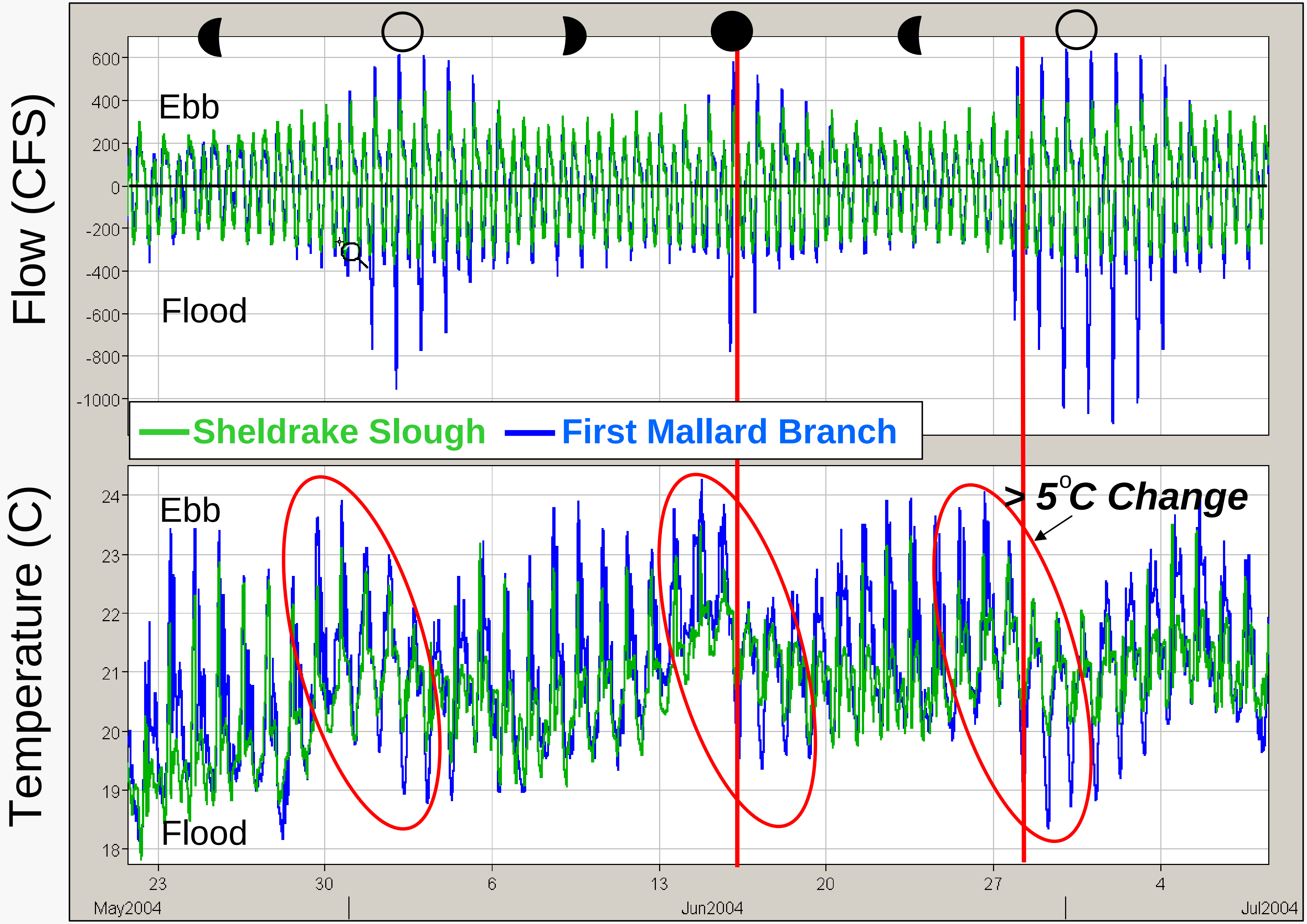
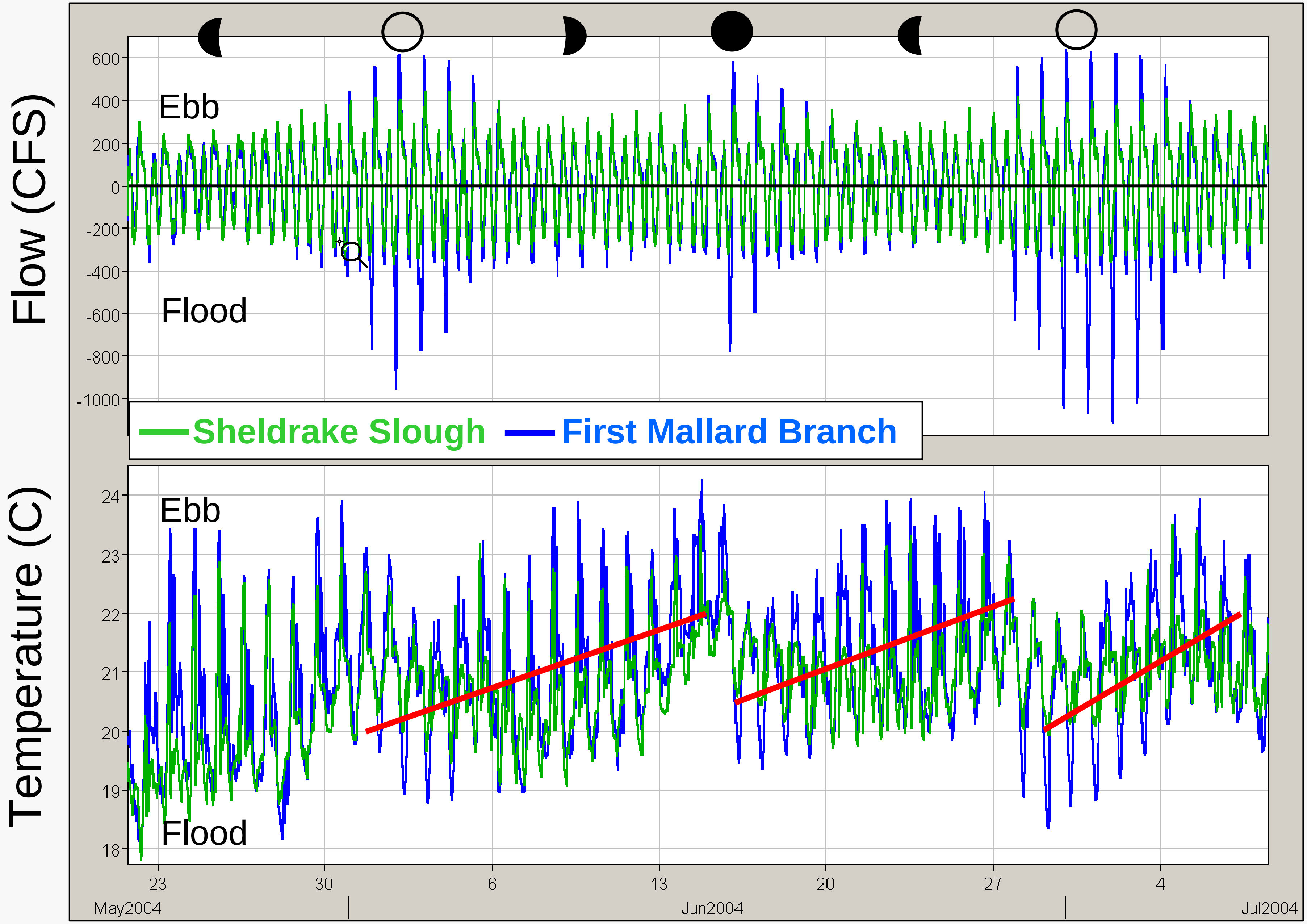


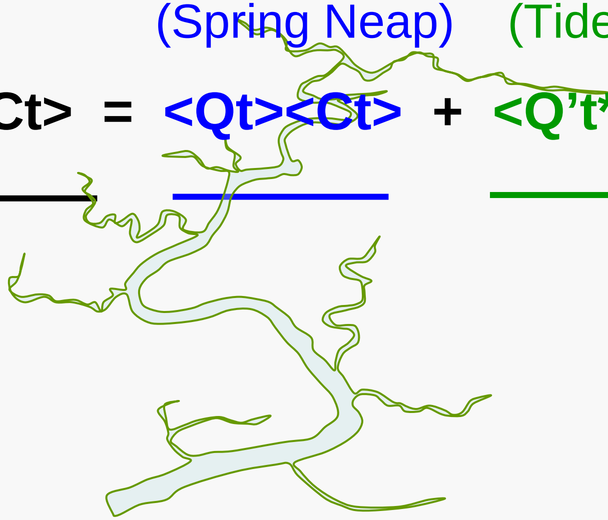
Flow and Temperature Variability

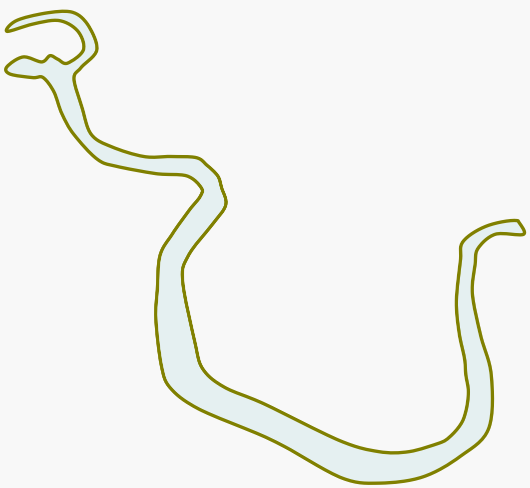


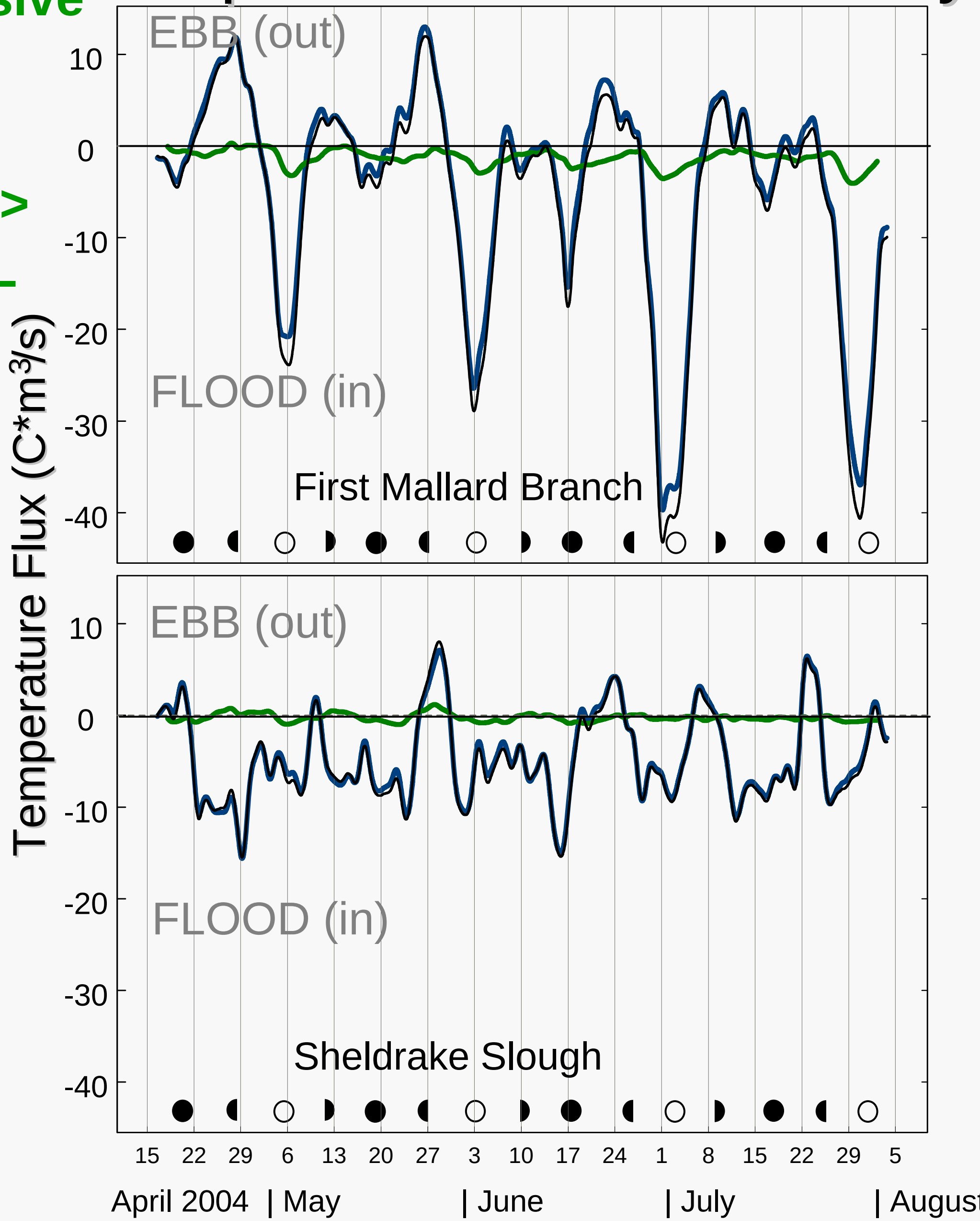
Temperature Flux Variability

Total Flux = **Advective Flux** (Spring Neap) + **Dispersive Flux** (Tides)

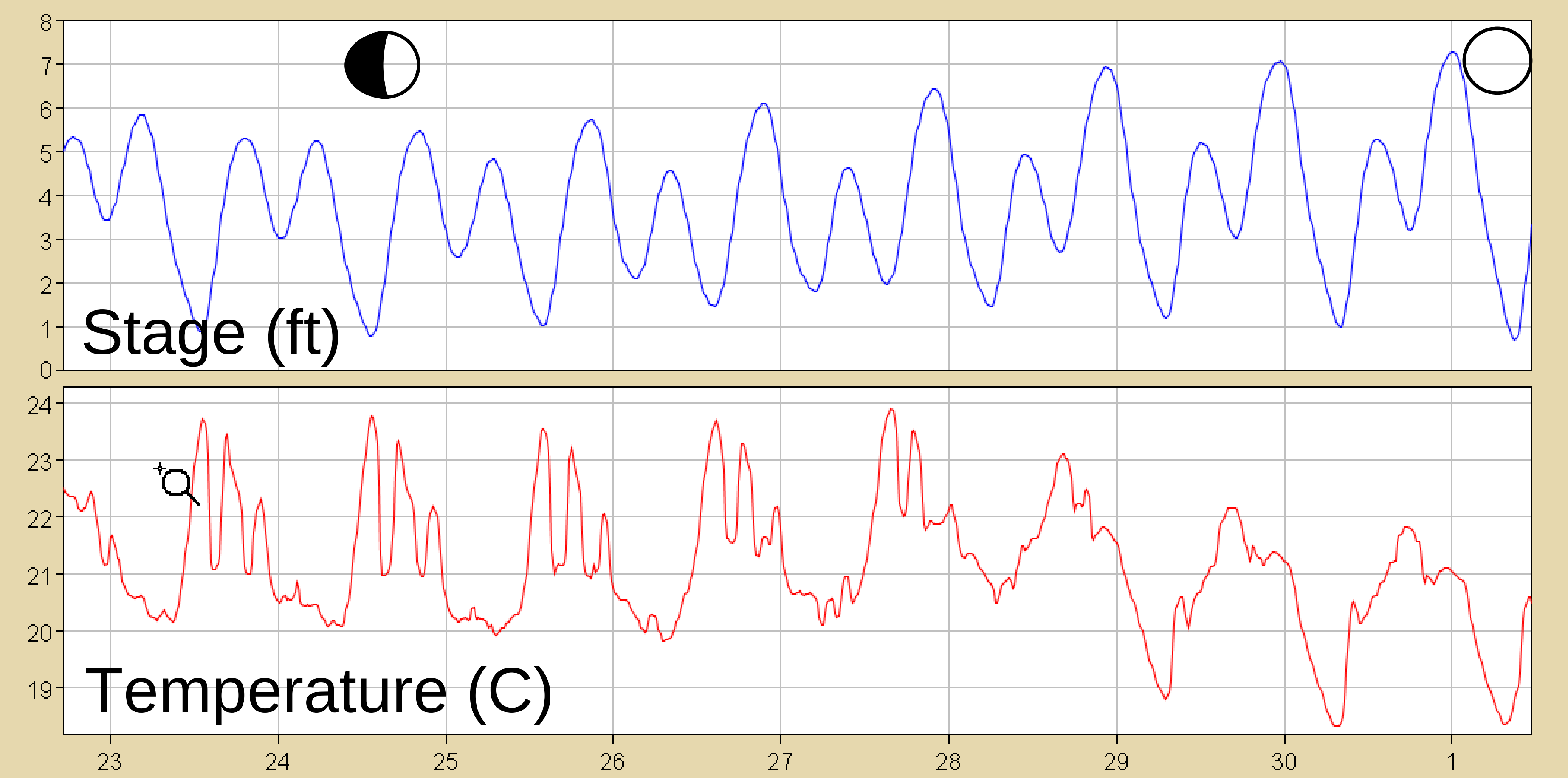
<Qt*Ct> = **<Qt><Ct>** + **<Q’t*C’t>**





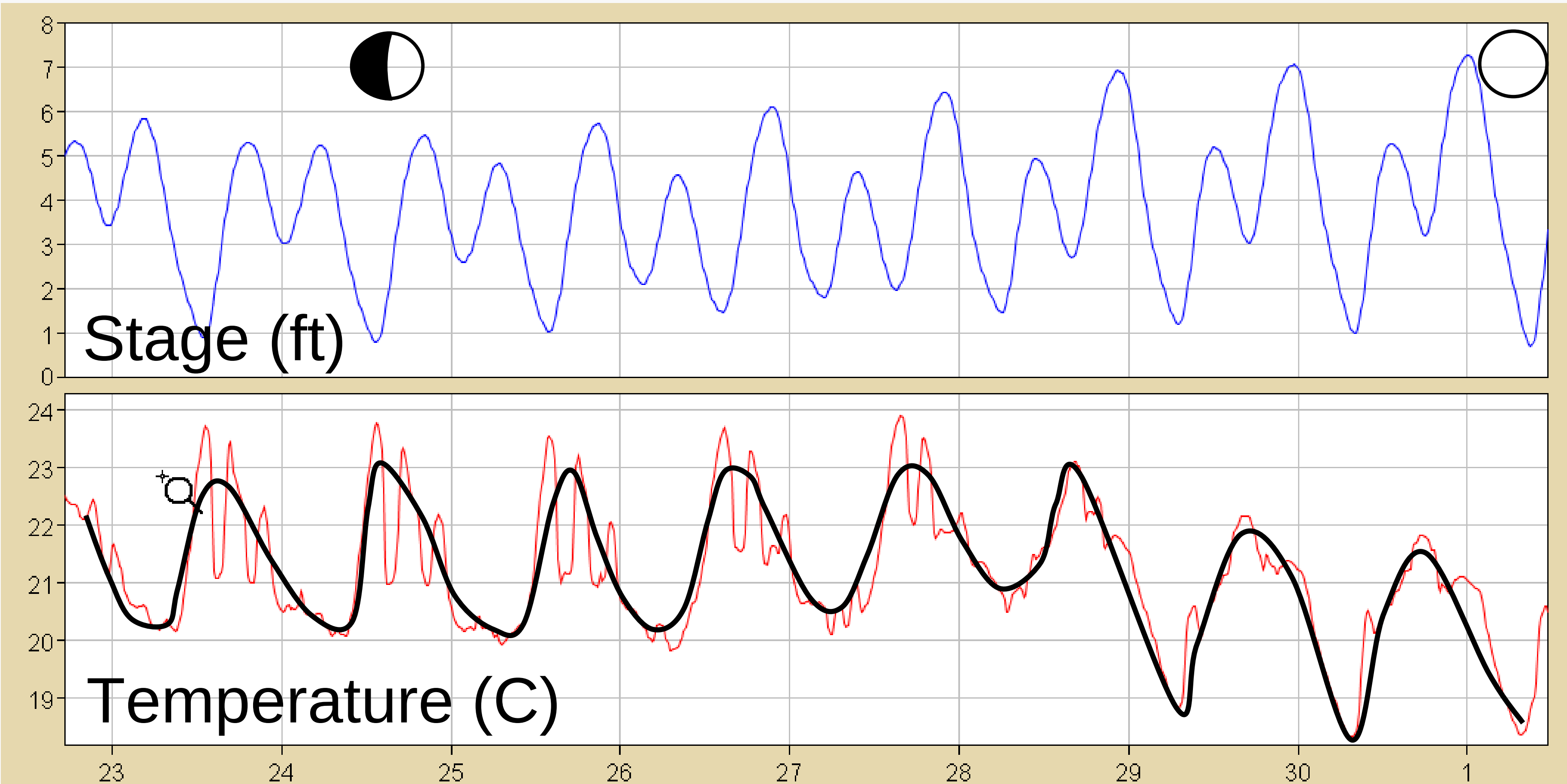


Consider some variability drivers on First Mallard temperature



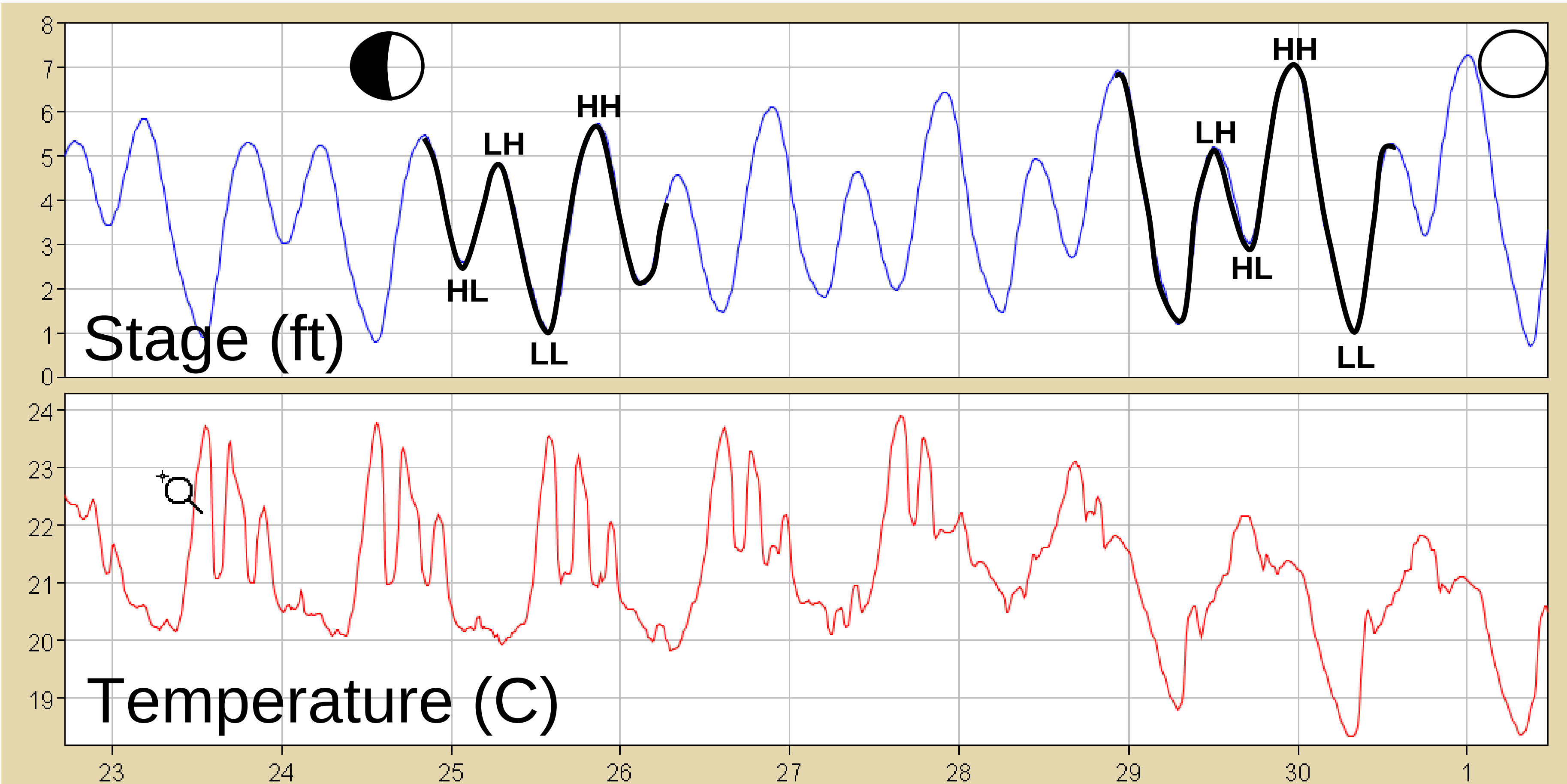
End of June 2004

Variability Drivers: Diel heating/cooling



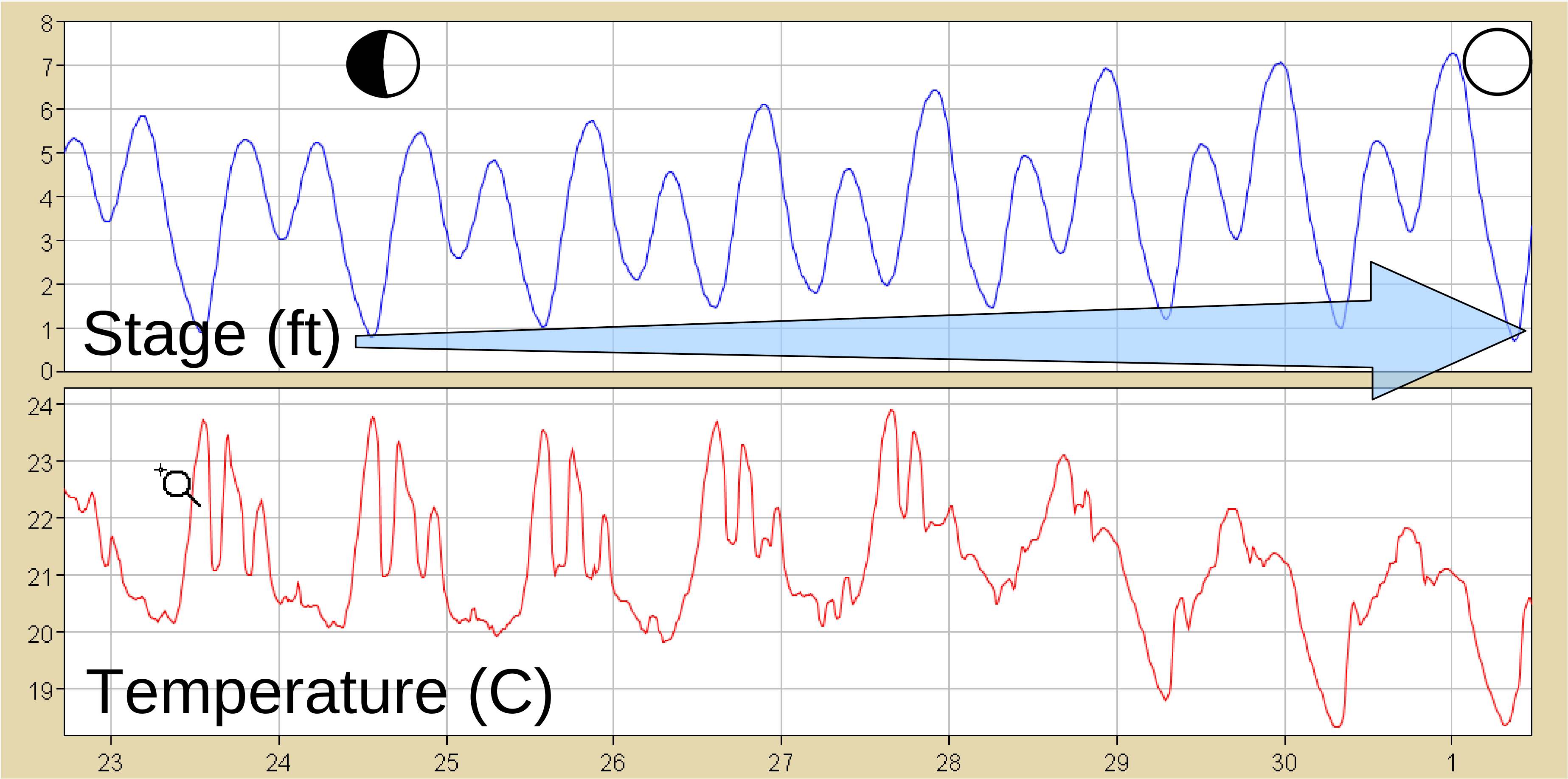
End of June 2004

Variability Drivers: Mixed semi-diurnal tidal asymmetry



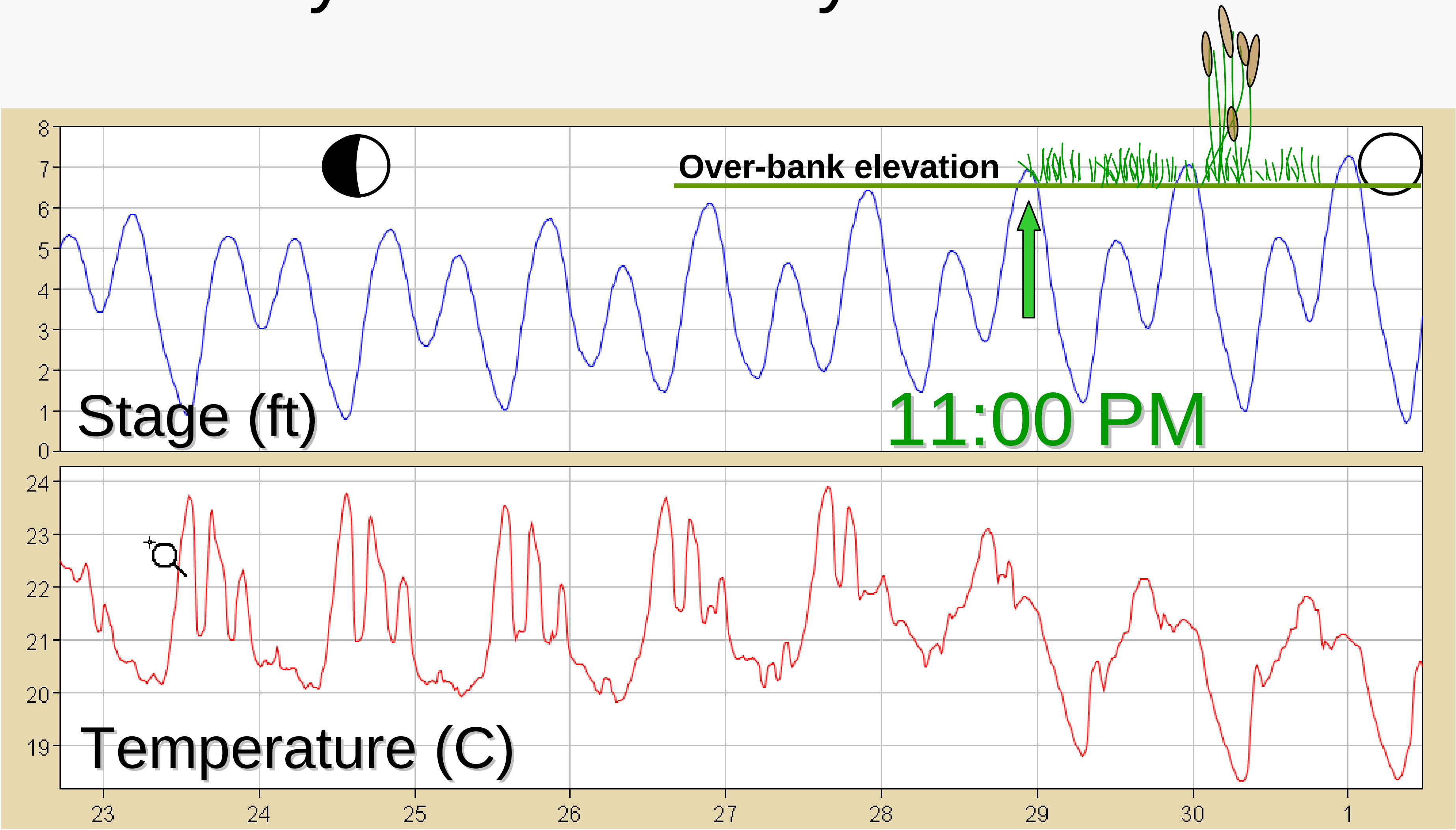
End of June 2004

Variability Drivers: Tide strength



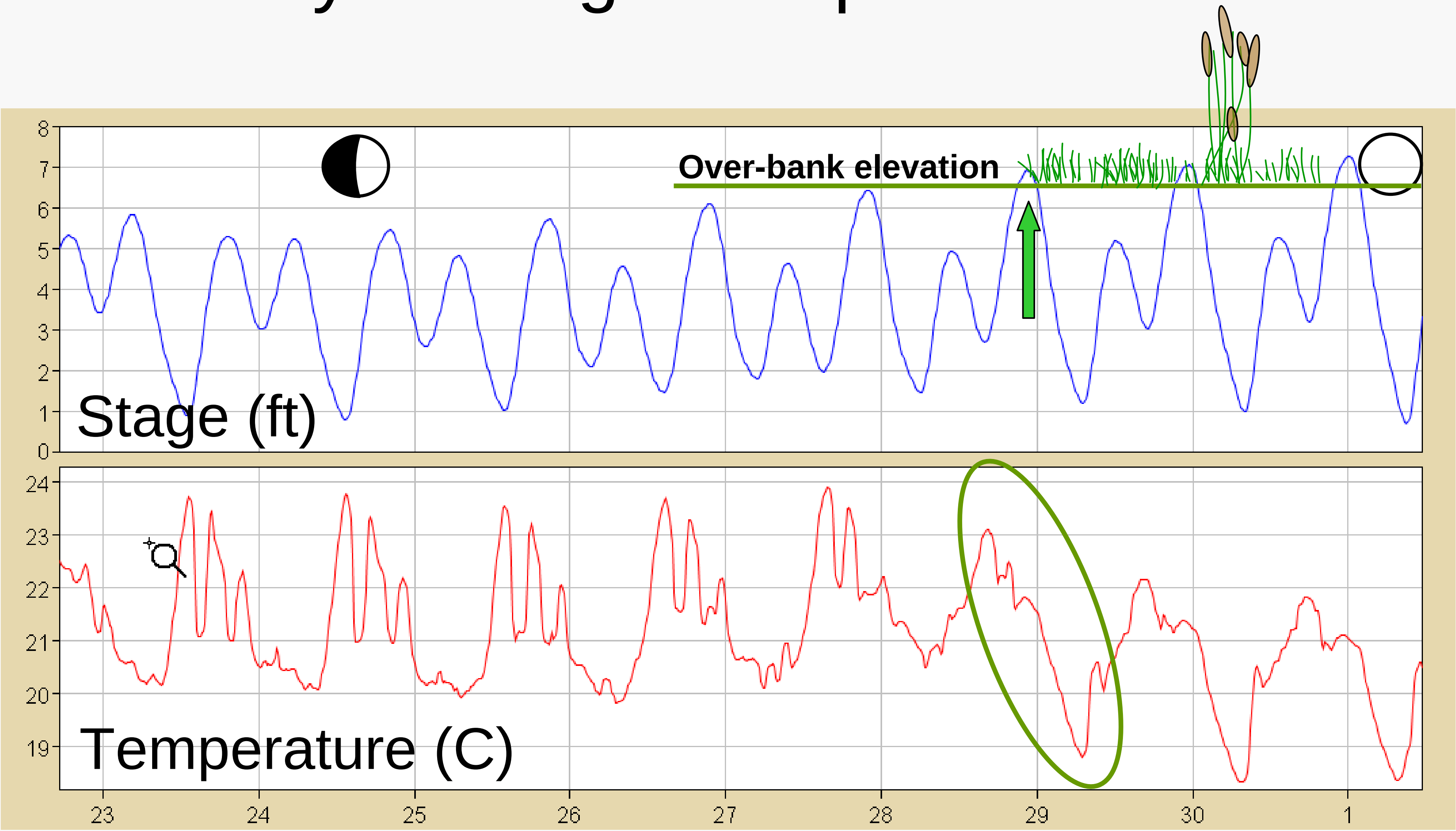
End of June 2004

Variability Drivers: 335 yr HT Precession



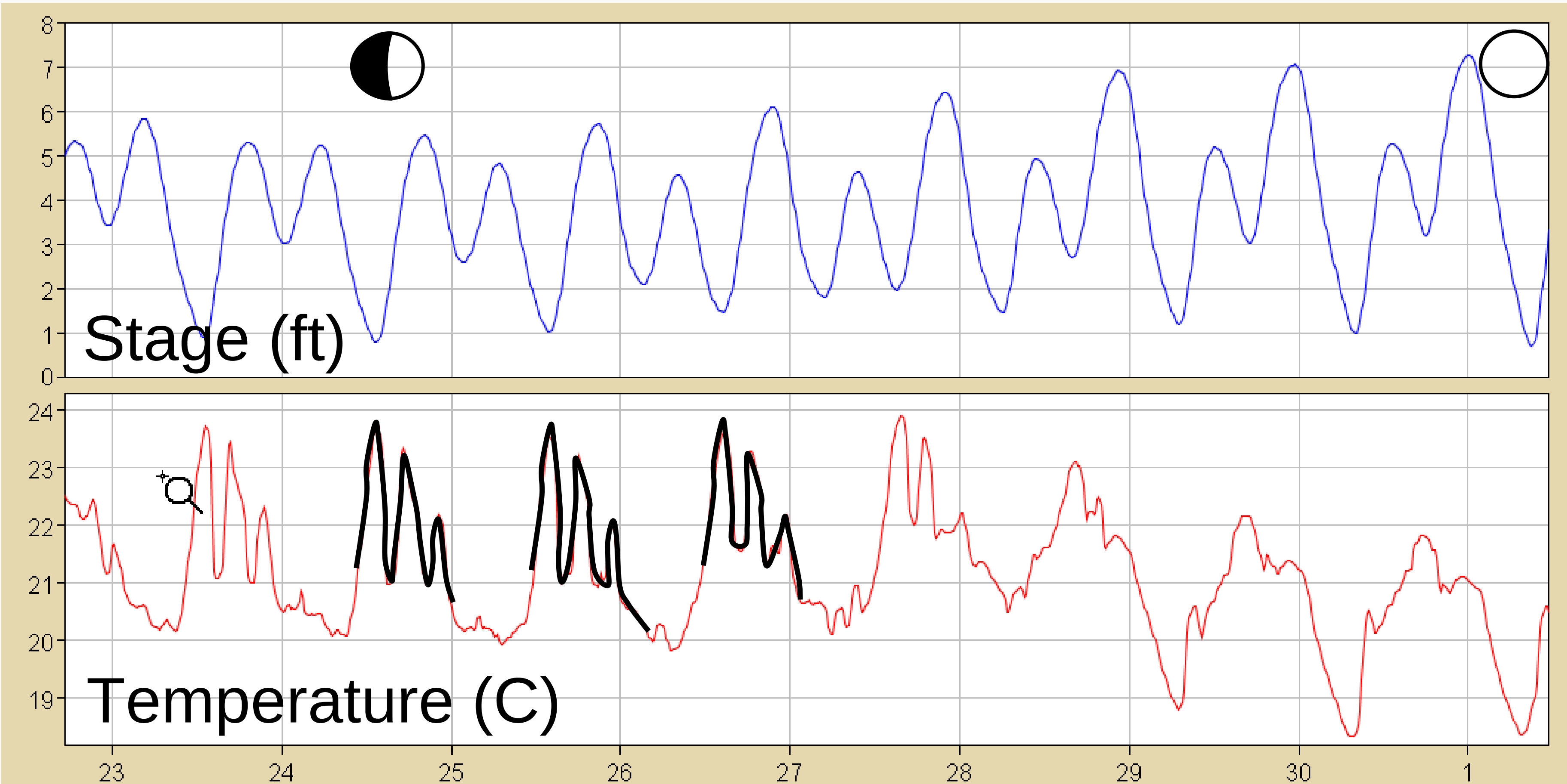
End of June 2004

Geometry filter: geomorphic thresholds



End of June 2004

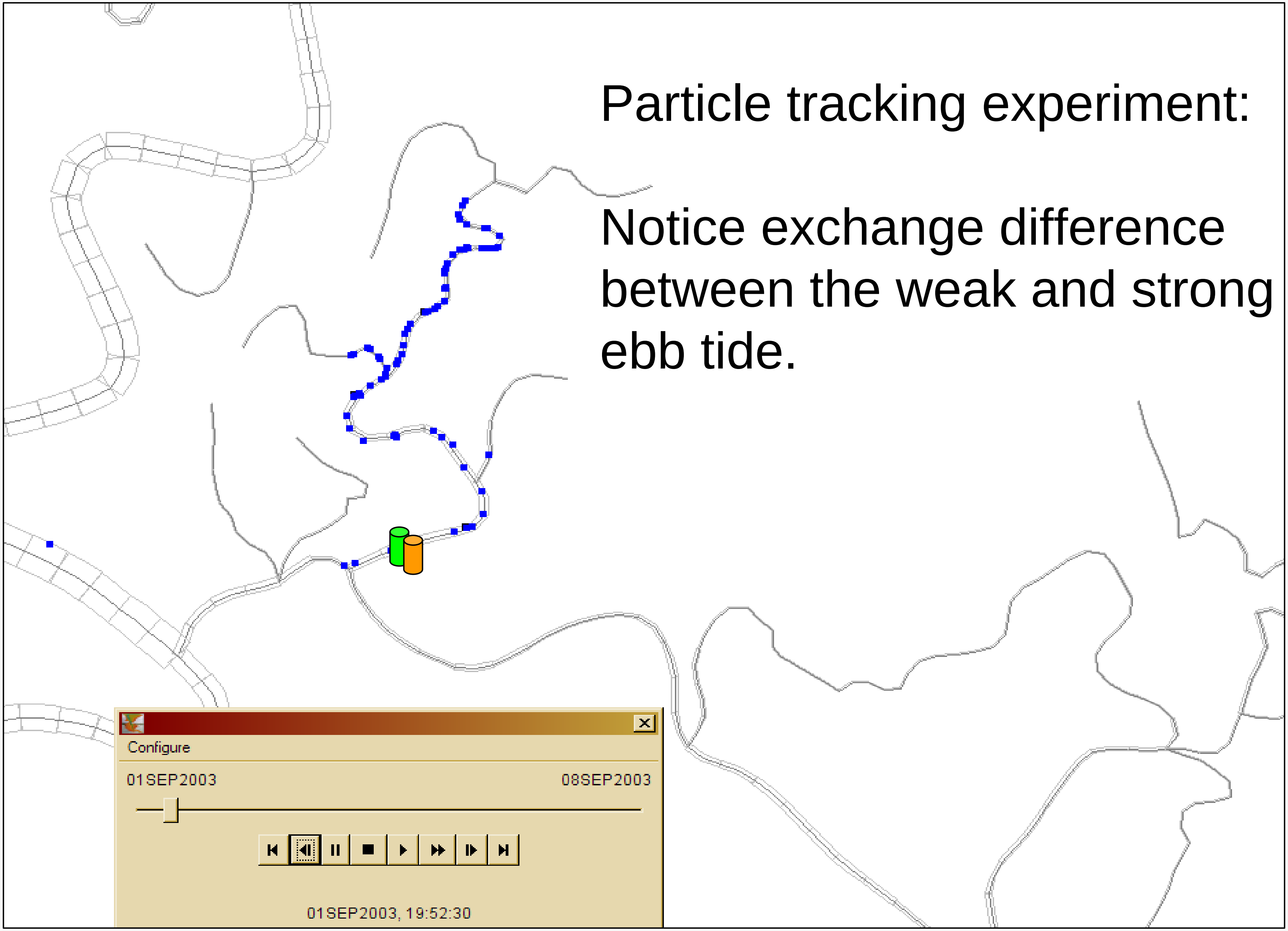
Geometry filter: slough connectivity and tidal excursion

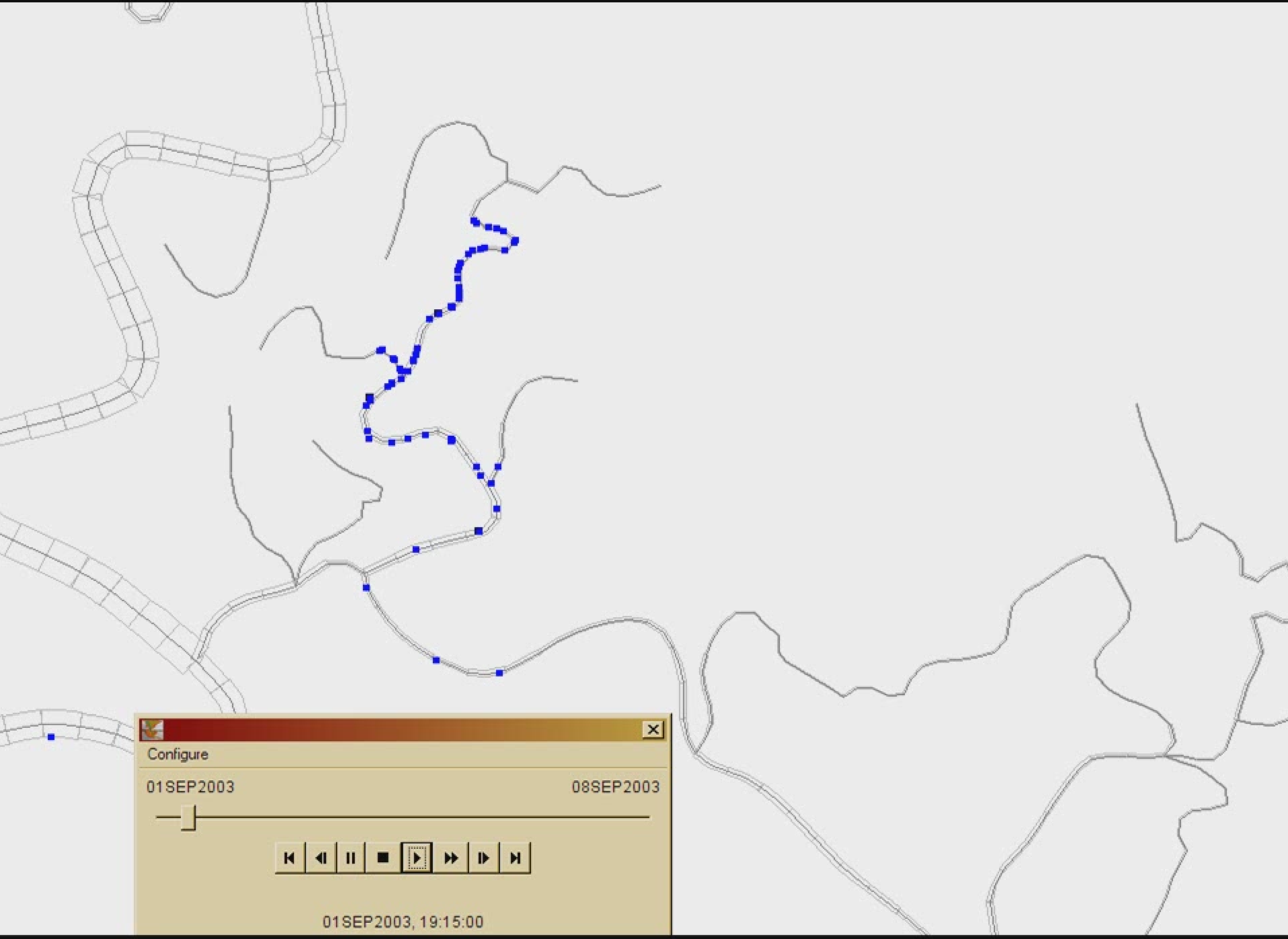


End of June 2004

Particle tracking experiment:

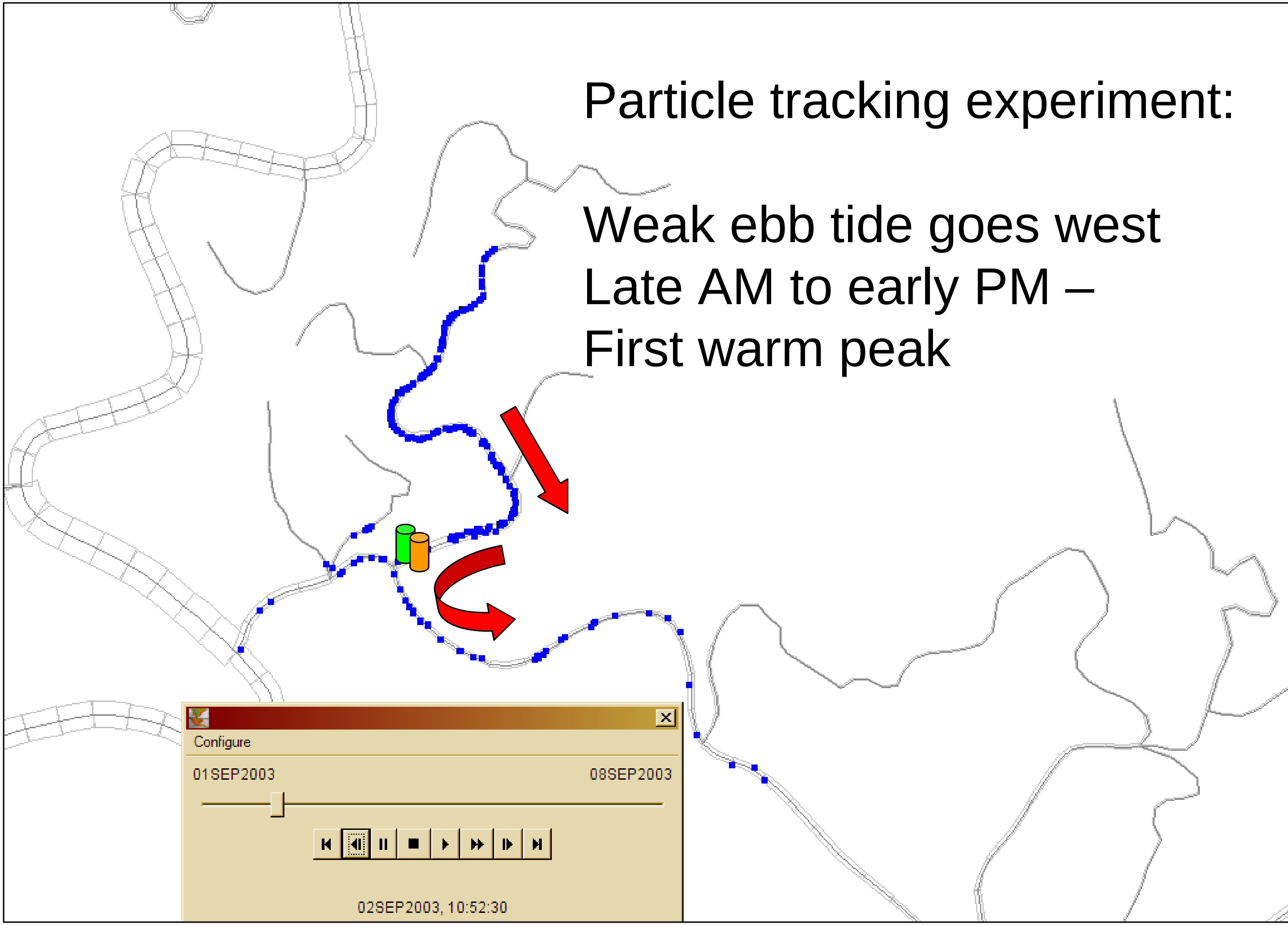
Notice exchange difference between the weak and strong ebb tide.




Configure
01SEP2003
08SEP2003
01SEP2003, 19:15:00

Particle tracking experiment:

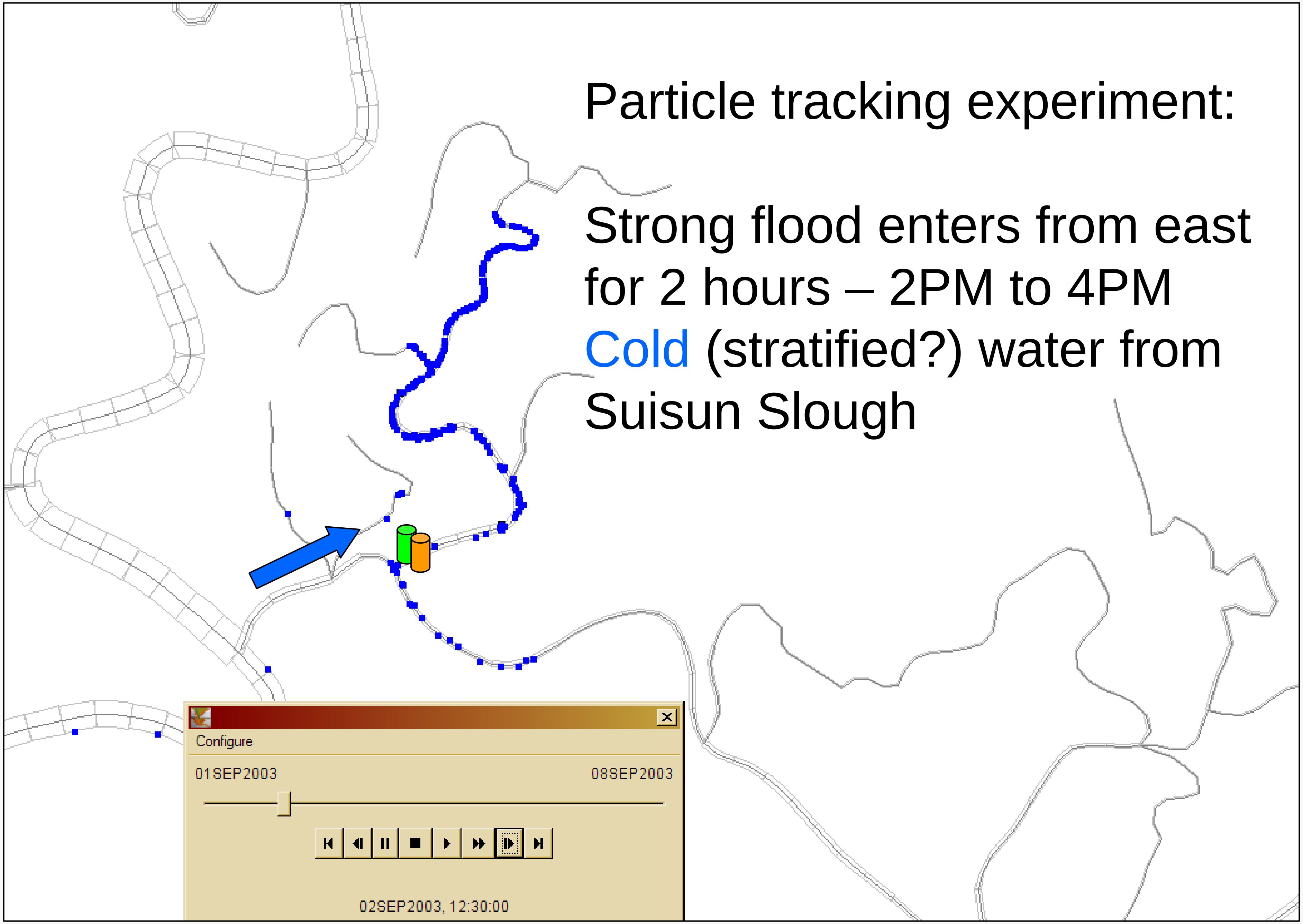
Weak ebb tide goes west
Late AM to early PM –
First warm peak



Particle tracking experiment:

Strong flood enters from east for 2 hours – 2PM to 4PM

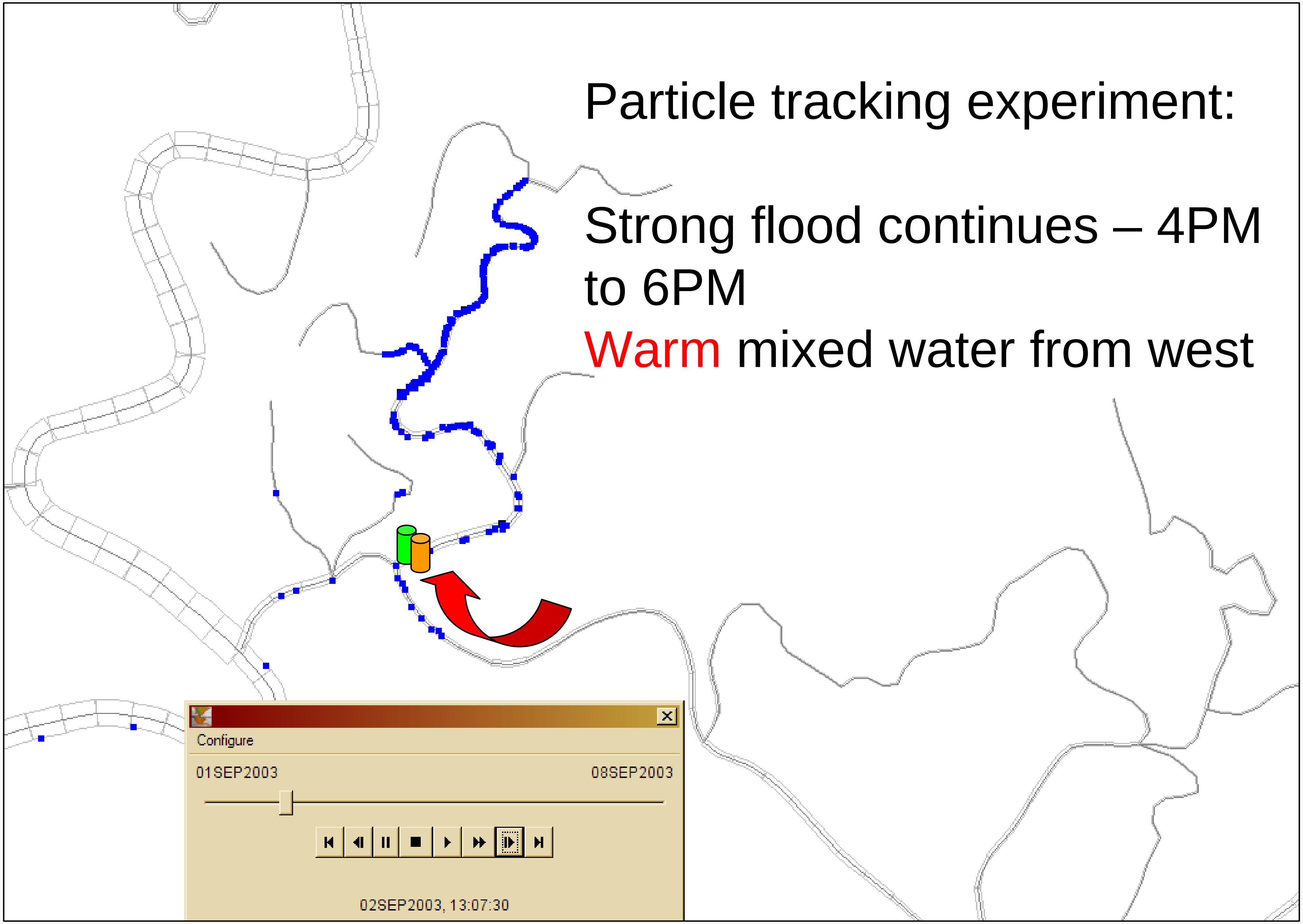
Cold (stratified?) water from Suisun Slough



Particle tracking experiment:

Strong flood continues – 4PM to 6PM

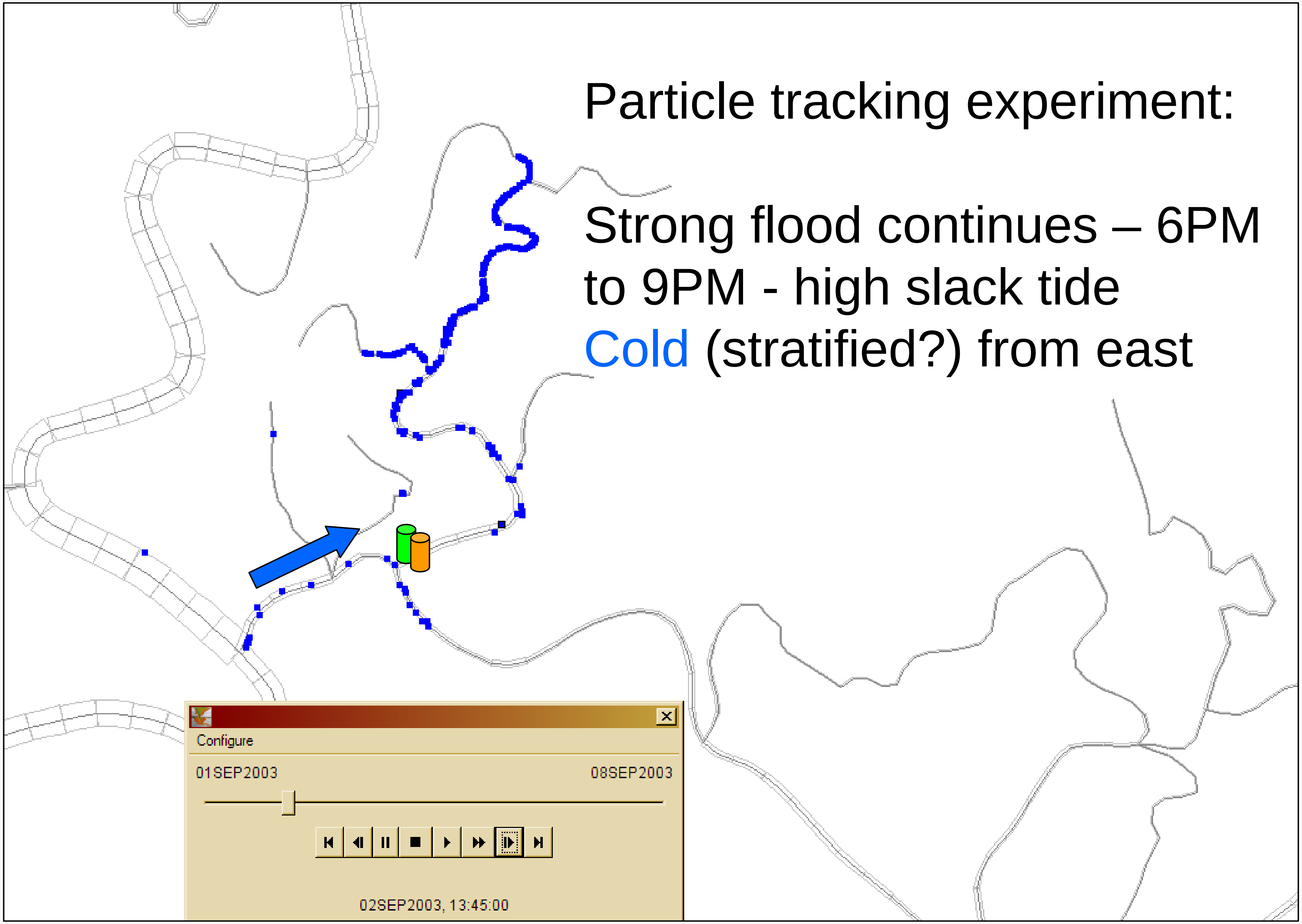
Warm mixed water from west



Particle tracking experiment:

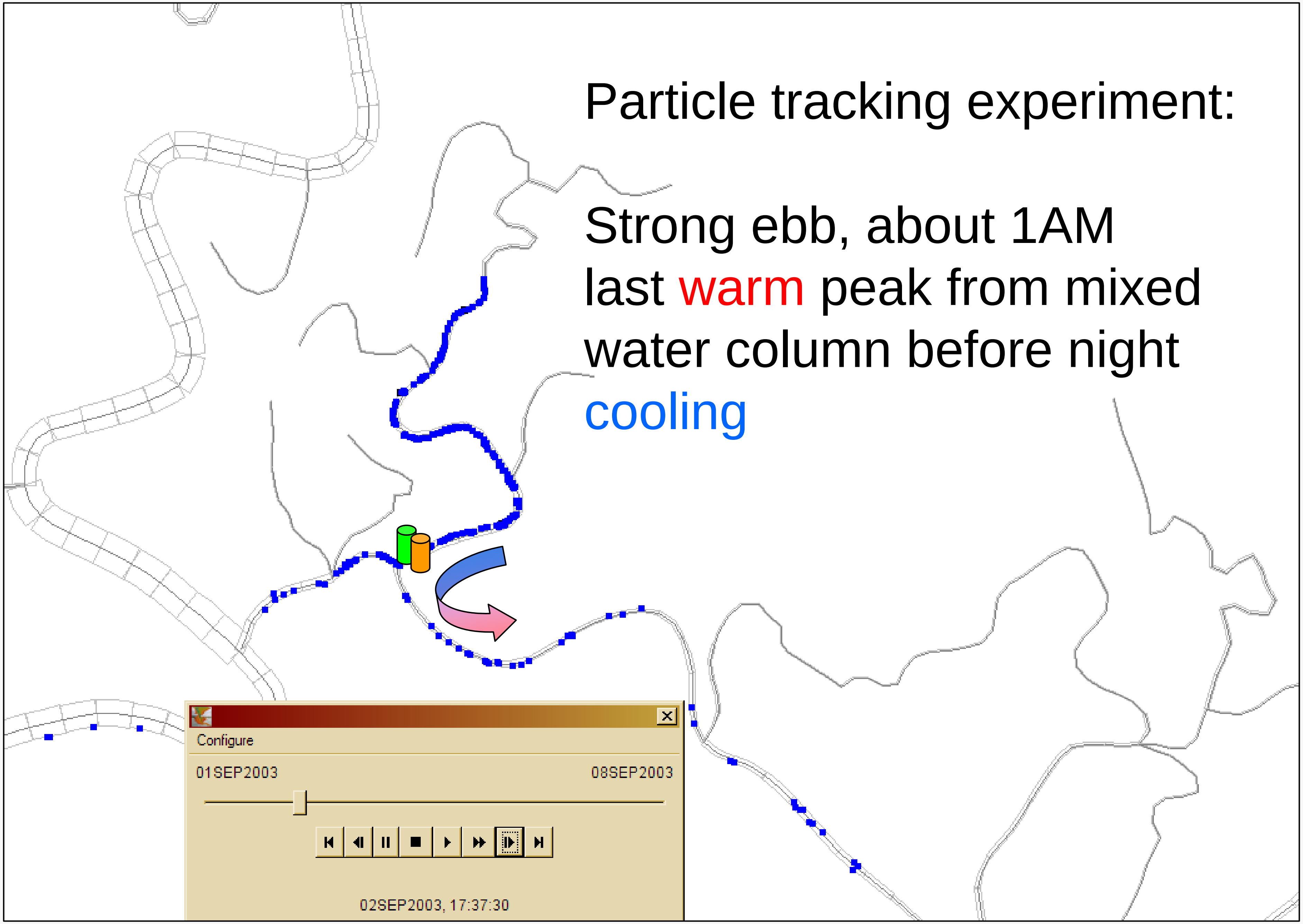
Strong flood continues – 6PM to 9PM - high slack tide

Cold (stratified?) from east

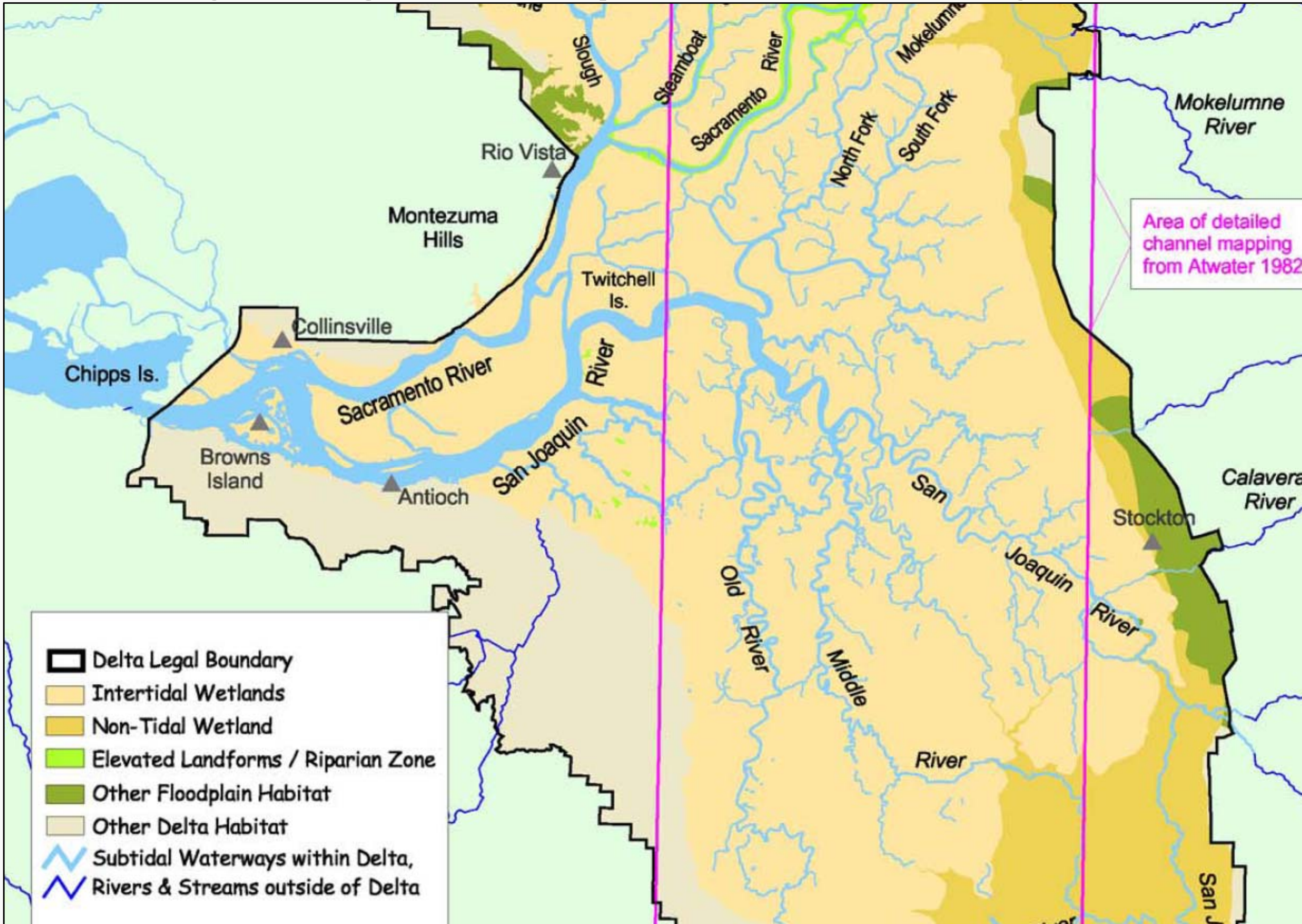


Particle tracking experiment:

Strong ebb, about 1AM
last warm peak from mixed water column before night cooling



Hydrogeomorphic variability lost

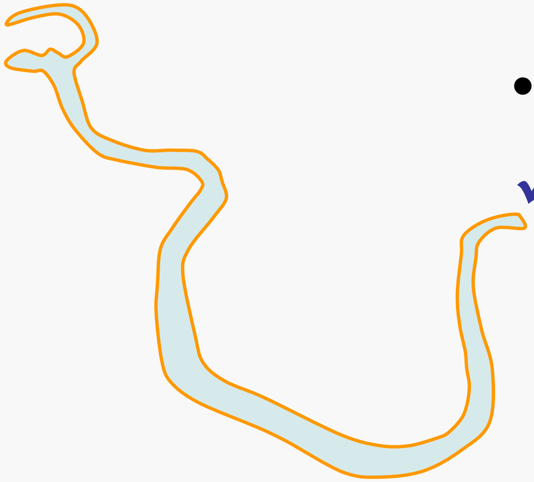


Bay Institute; based on Atwater 1982

Key ideas

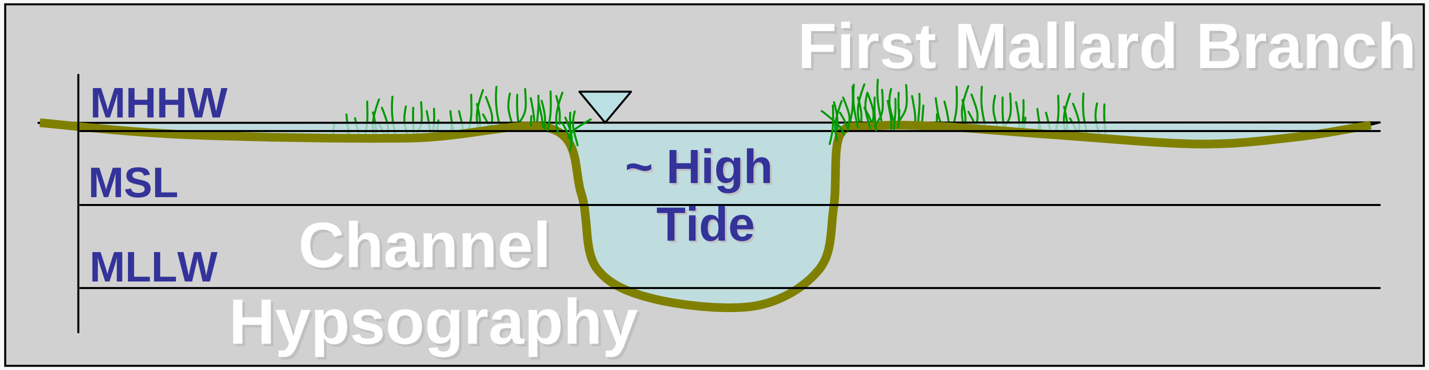
- Estuaries generate variability by interaction of physical drivers and “geometry as filter” at the land-water-air interface.
- Geometry filters drivers at all time scales
- Natural tidal creek systems have more complex land-water-air interfaces
- More complex geometry begets more variable gradient response.
- The “why does variability matter?” corollary:

✓ Native plants/fishes evolved in a more variable environment.

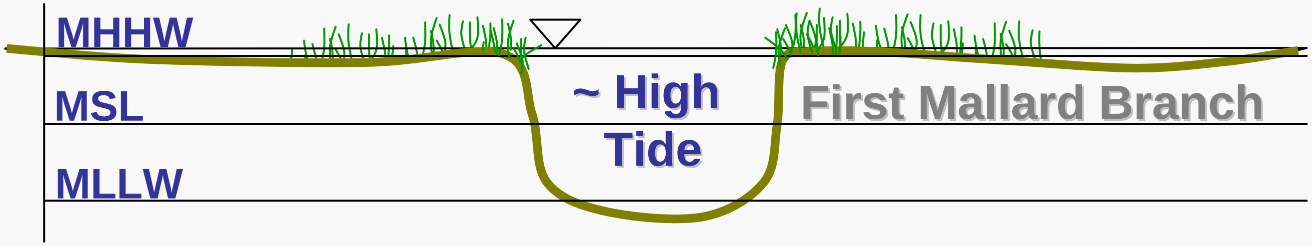


DRERIP Tidal Marsh Restoration “Outcome”

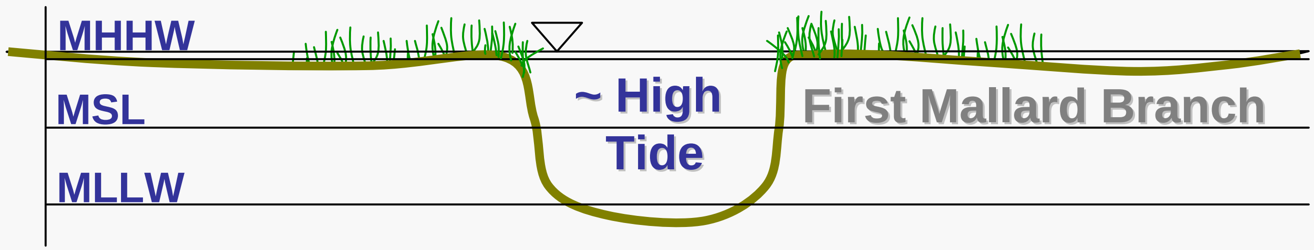
- “Locally provide areas of cool water refugia for delta smelt.”



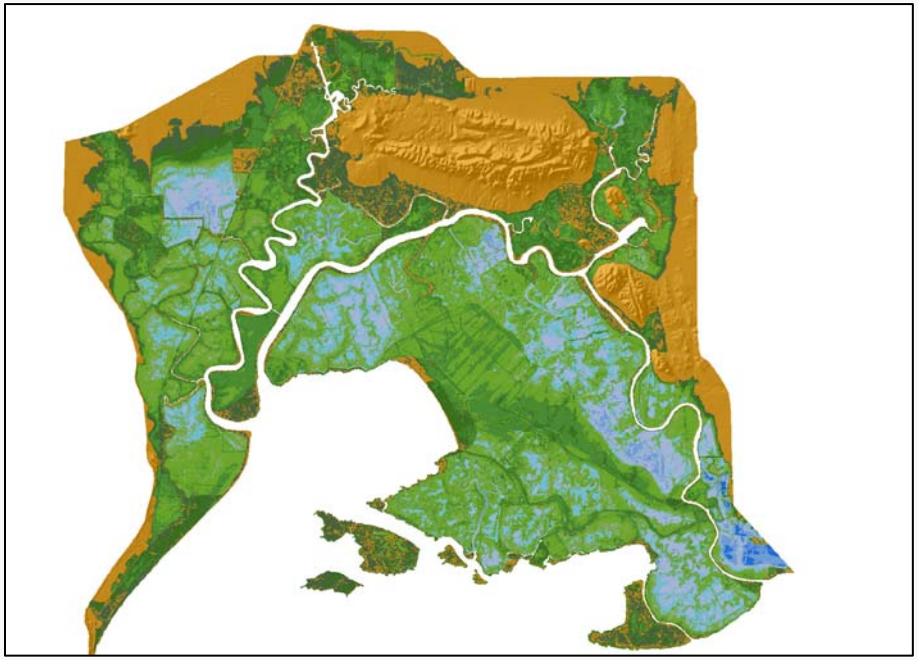
- We know something about land-water interface temperature dynamics for this shape:



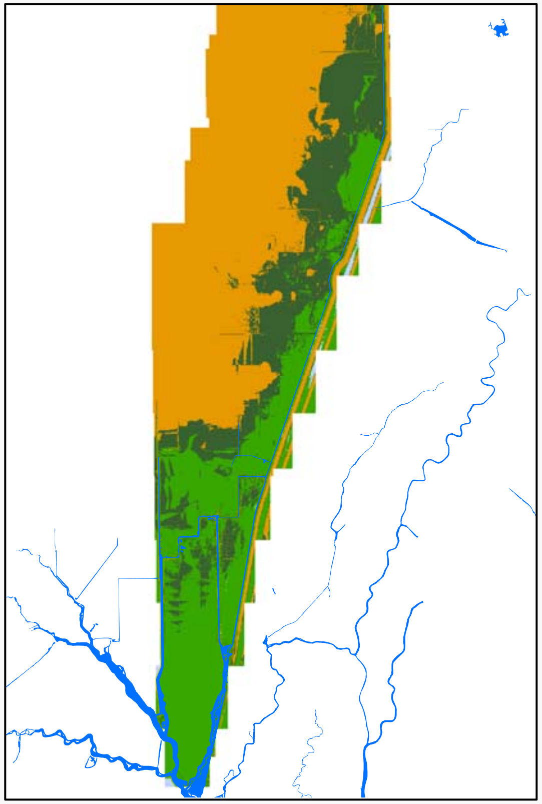
- We know something about land-water interface temperature dynamics for this shape:



- What about:

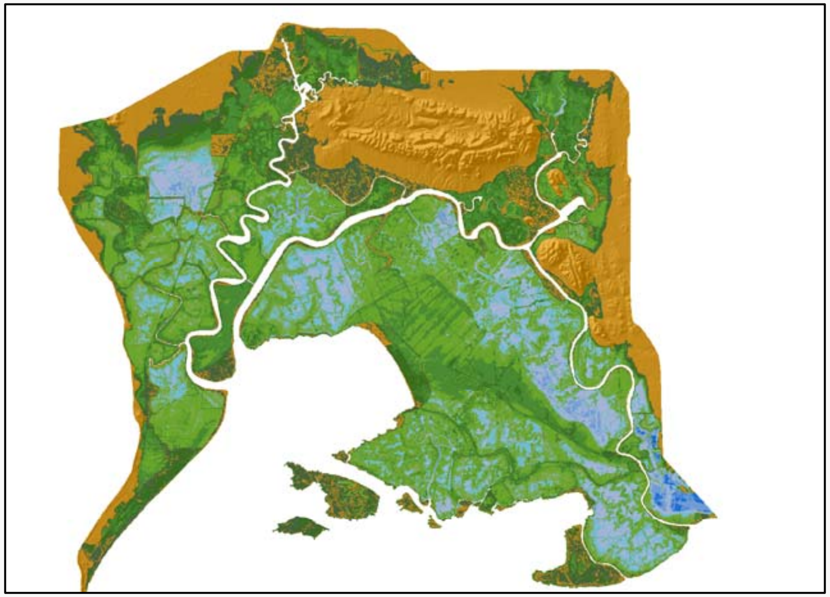


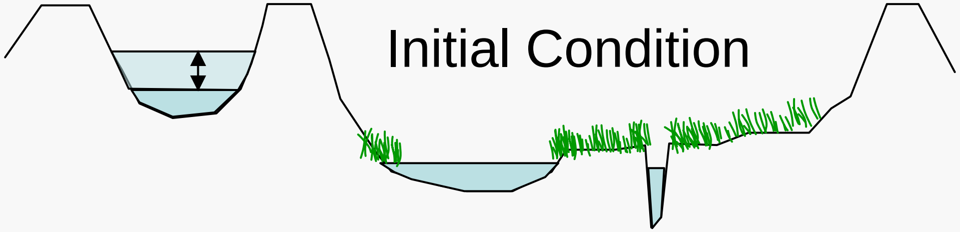
and



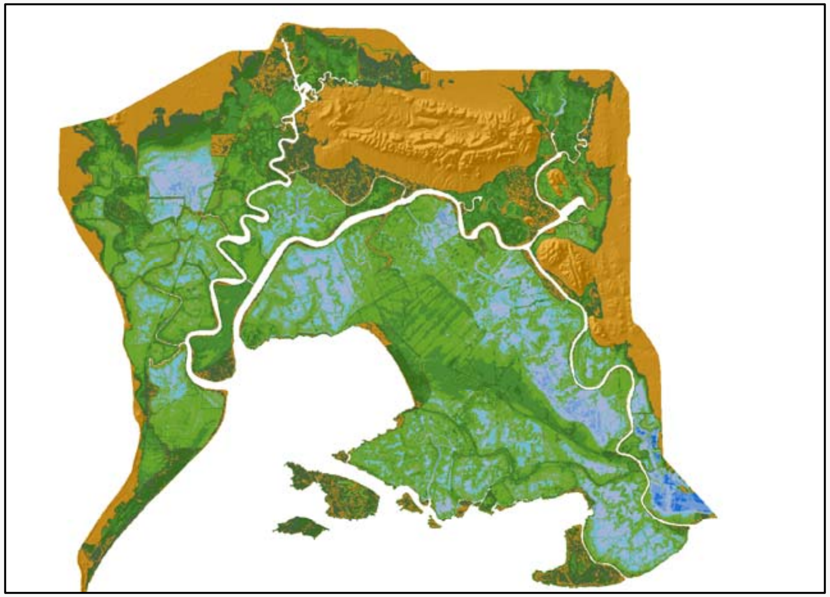
?

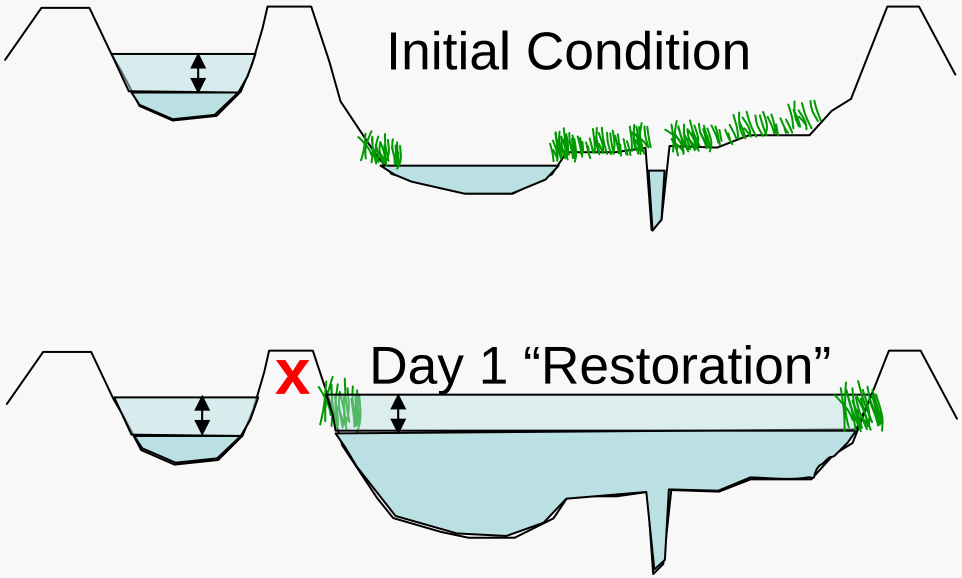
Suisun land-water interface characteristic



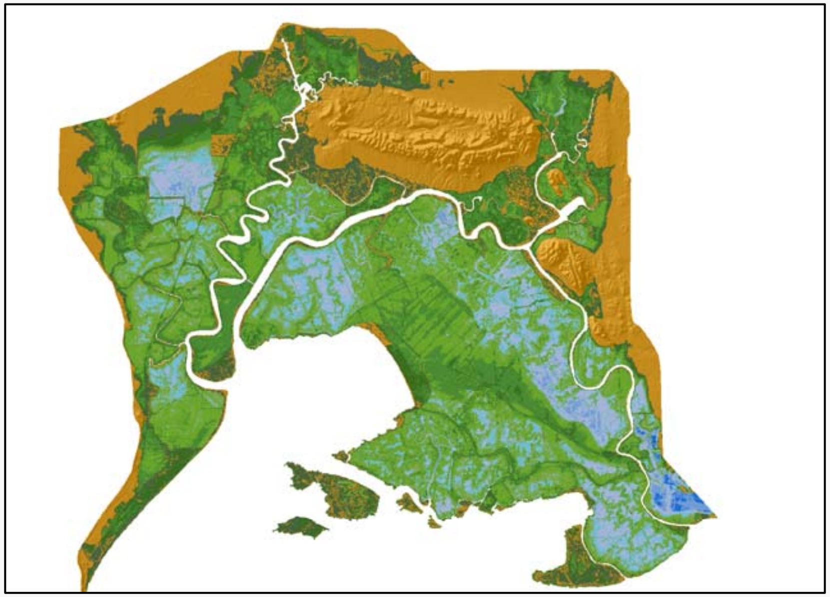


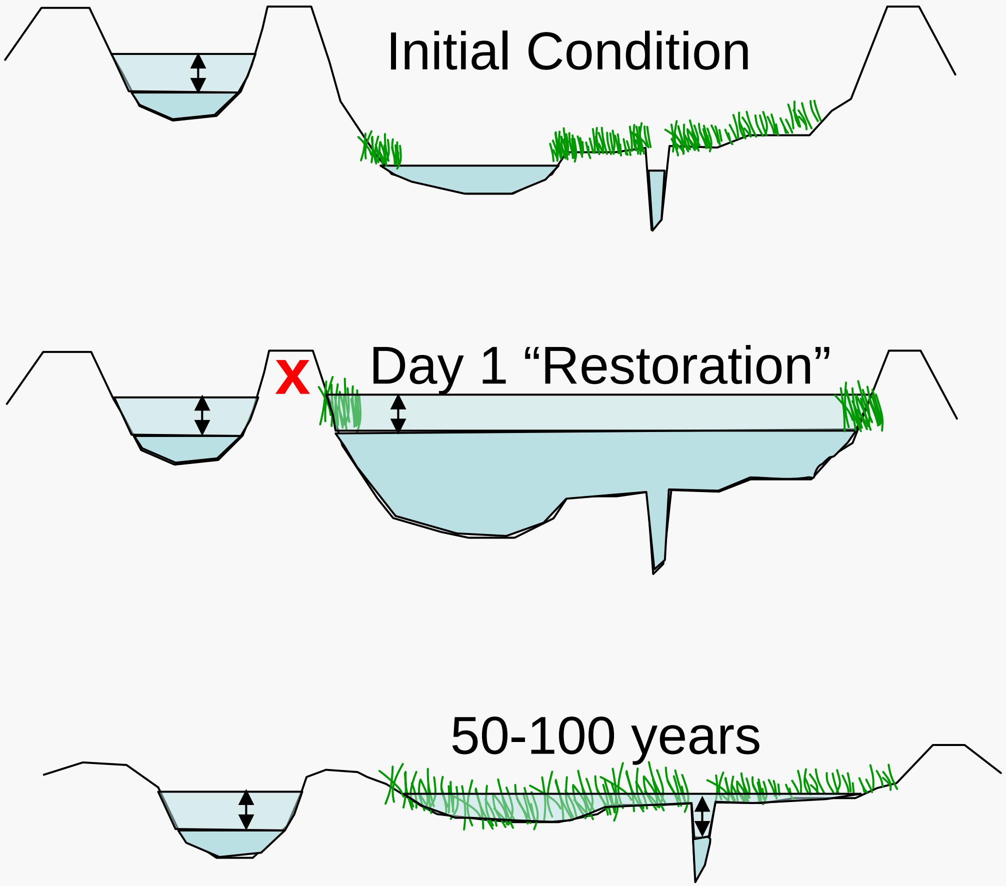
Suisun land-water interface characteristic



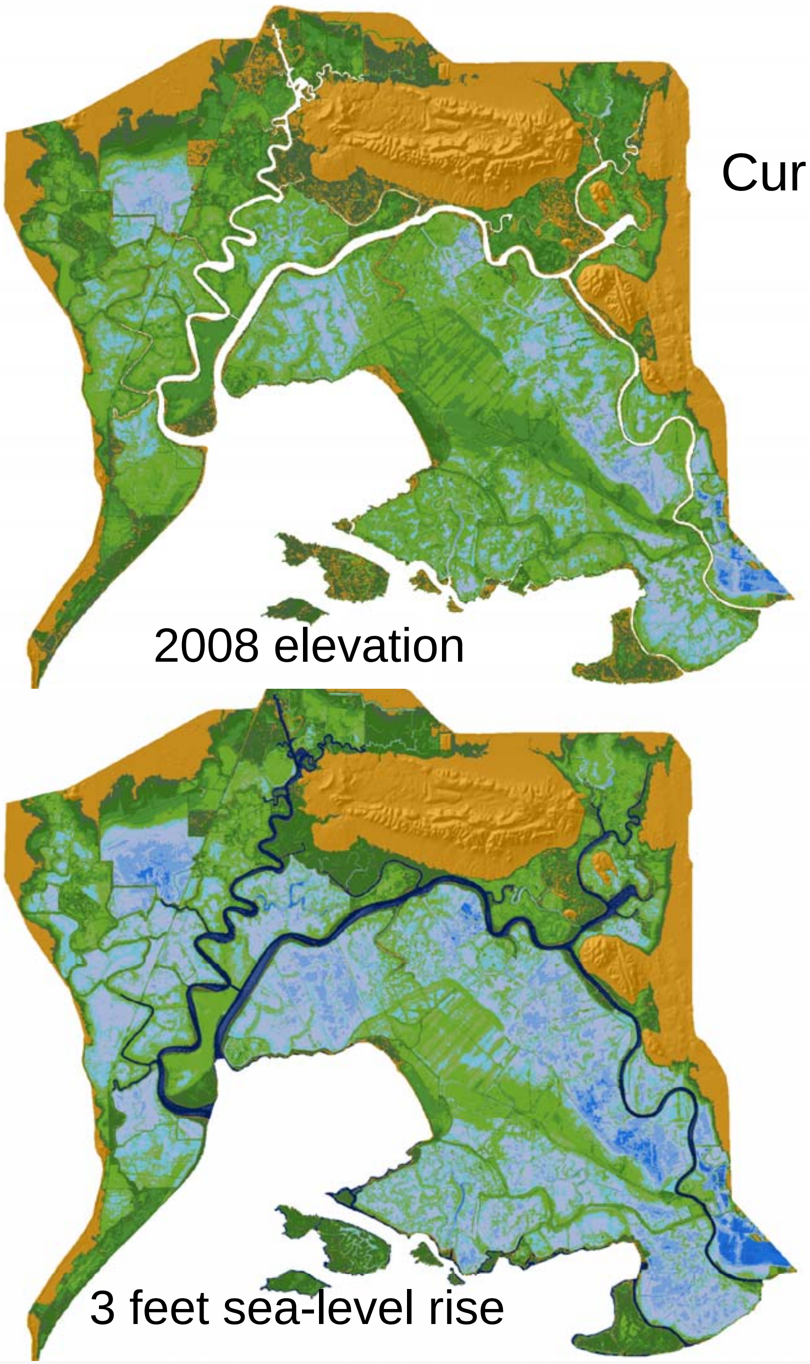


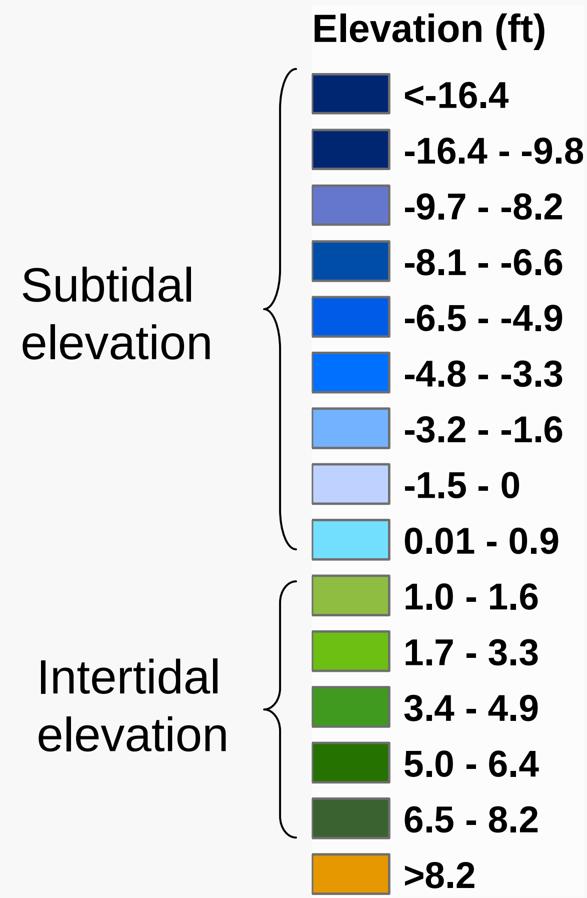
Suisun land-water interface characteristic



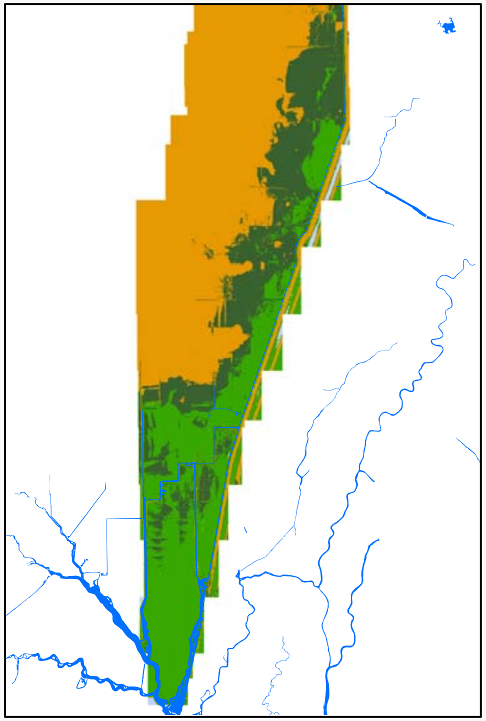


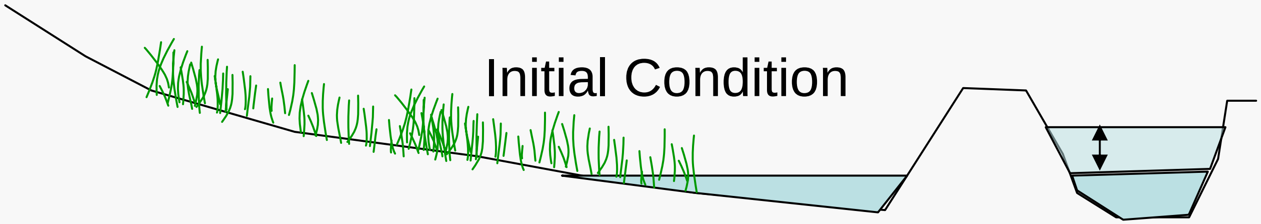
Suisun Marsh Elevation
Current Condition and 3 feet Sea-Level Rise



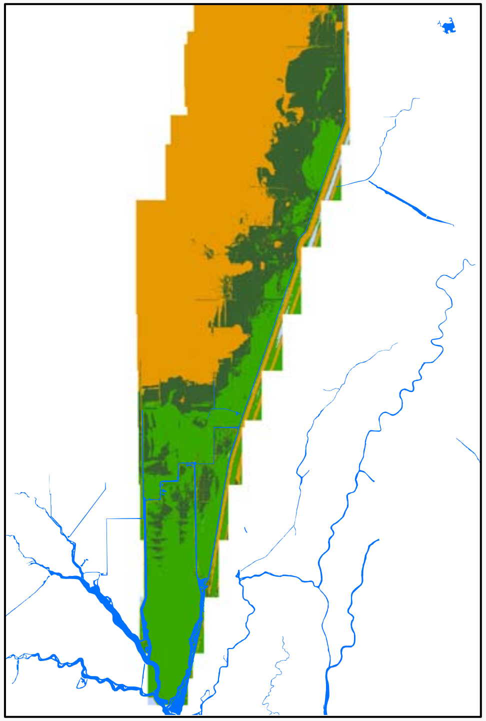


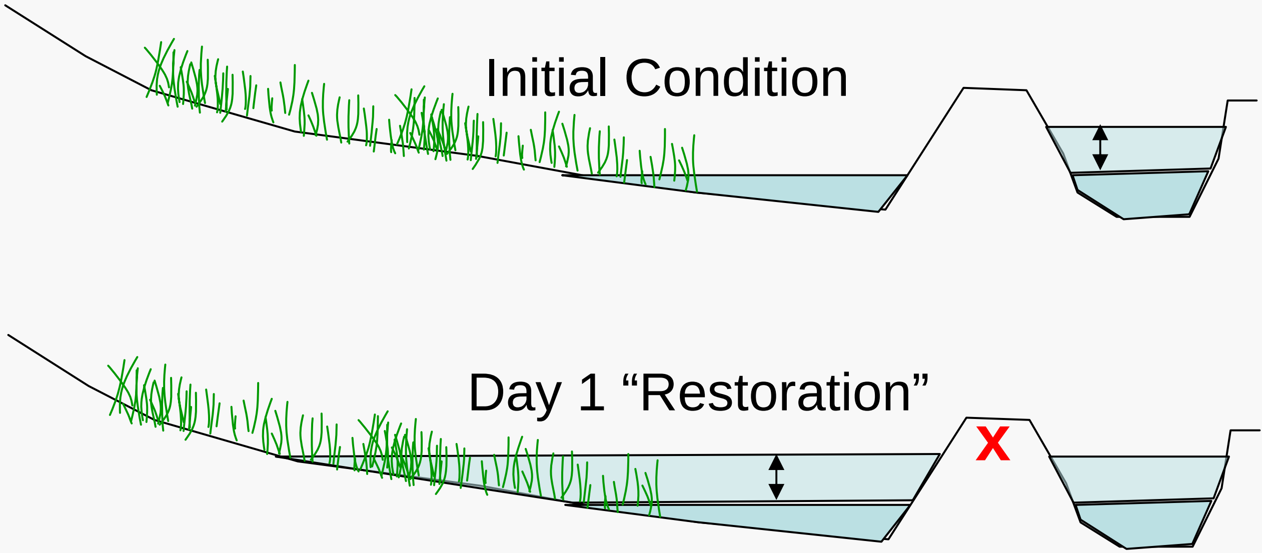
Yolo-Cache land-water interface characteristic



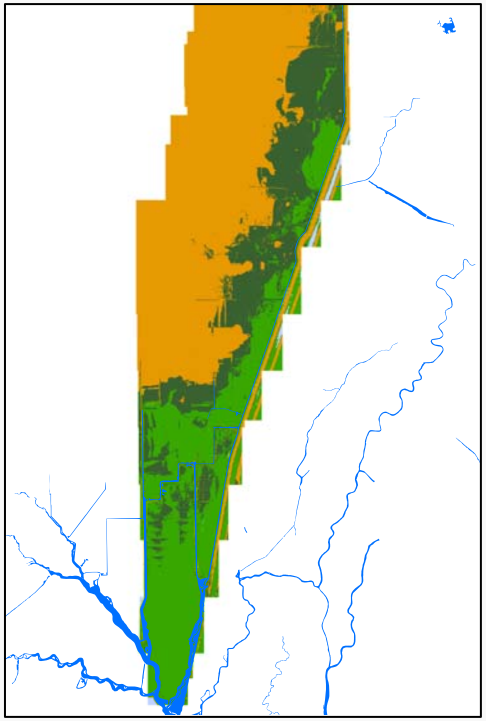


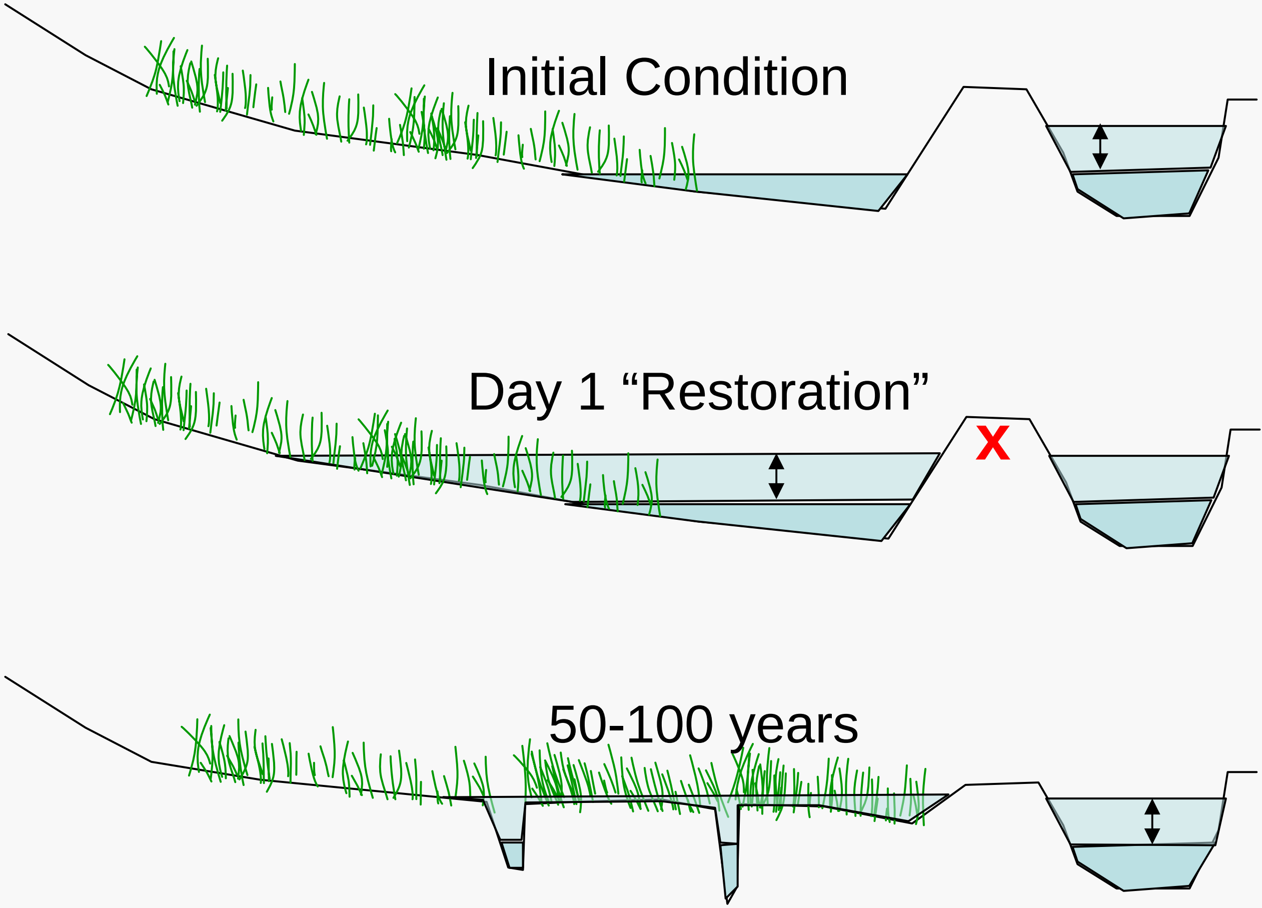
Yolo-Cache land-water interface characteristic





Yolo-Cache land-water interface characteristic



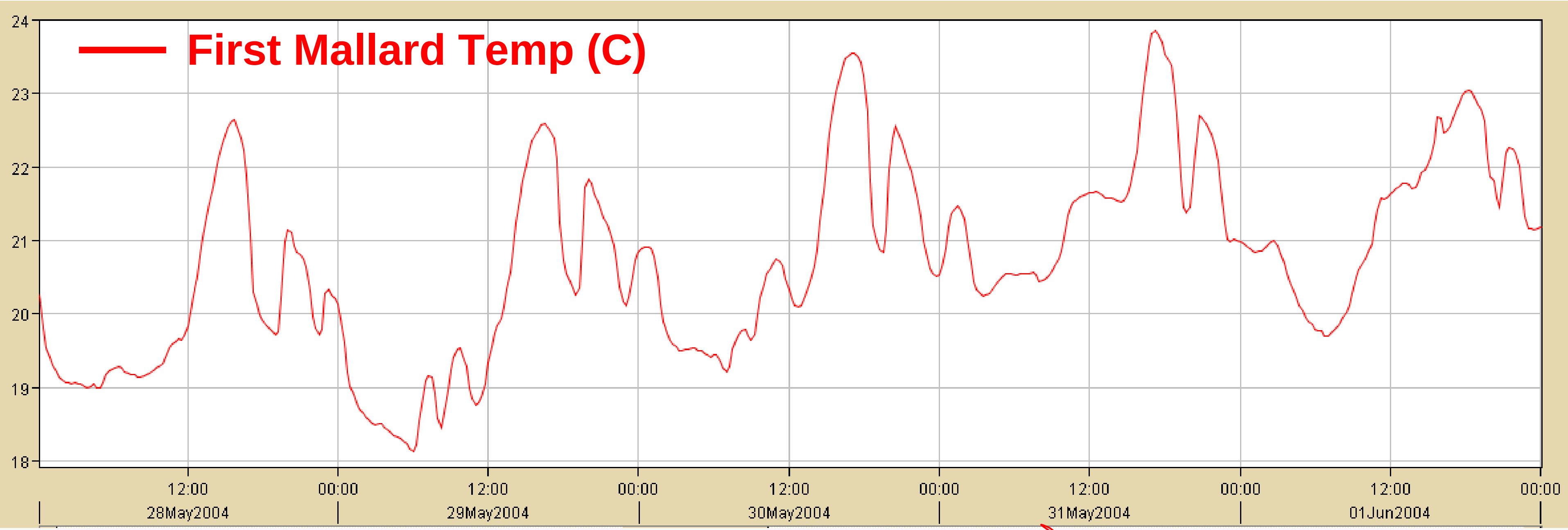


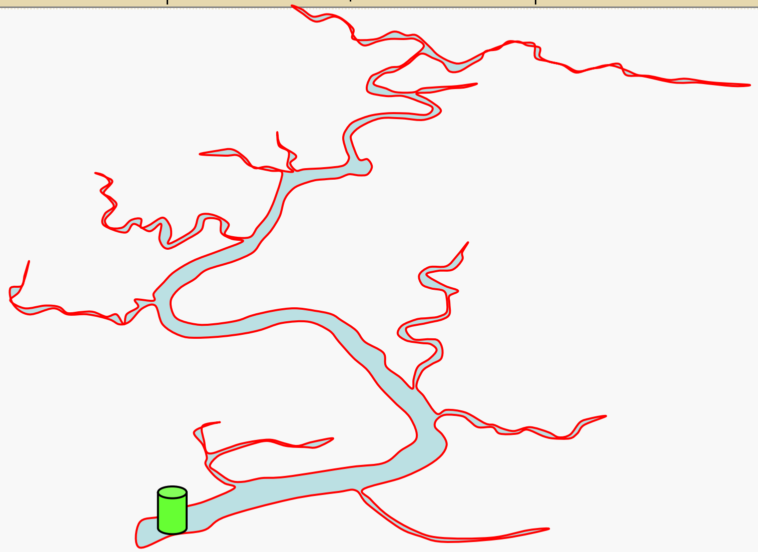
Thank you

- Steve Culberson
- Jon Burau
- Paul Massera
- Brad Tom
- Kate Le
- Terri Fong

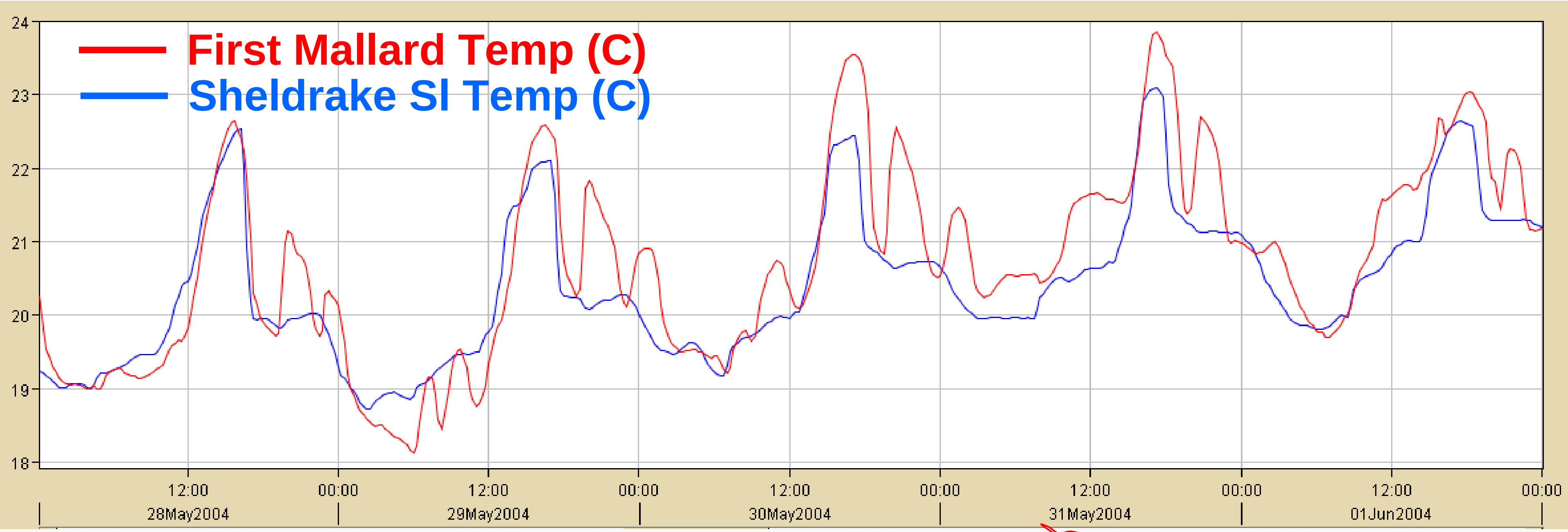
Additional slides

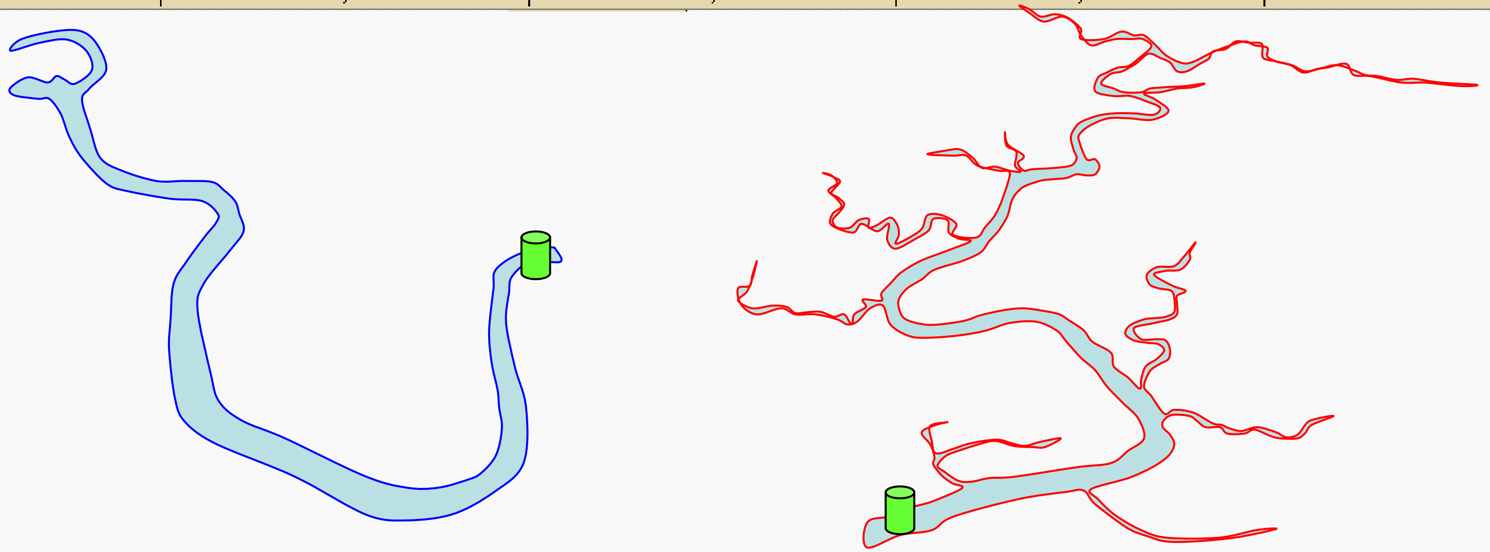
High frequency variability at First Mallard Branch



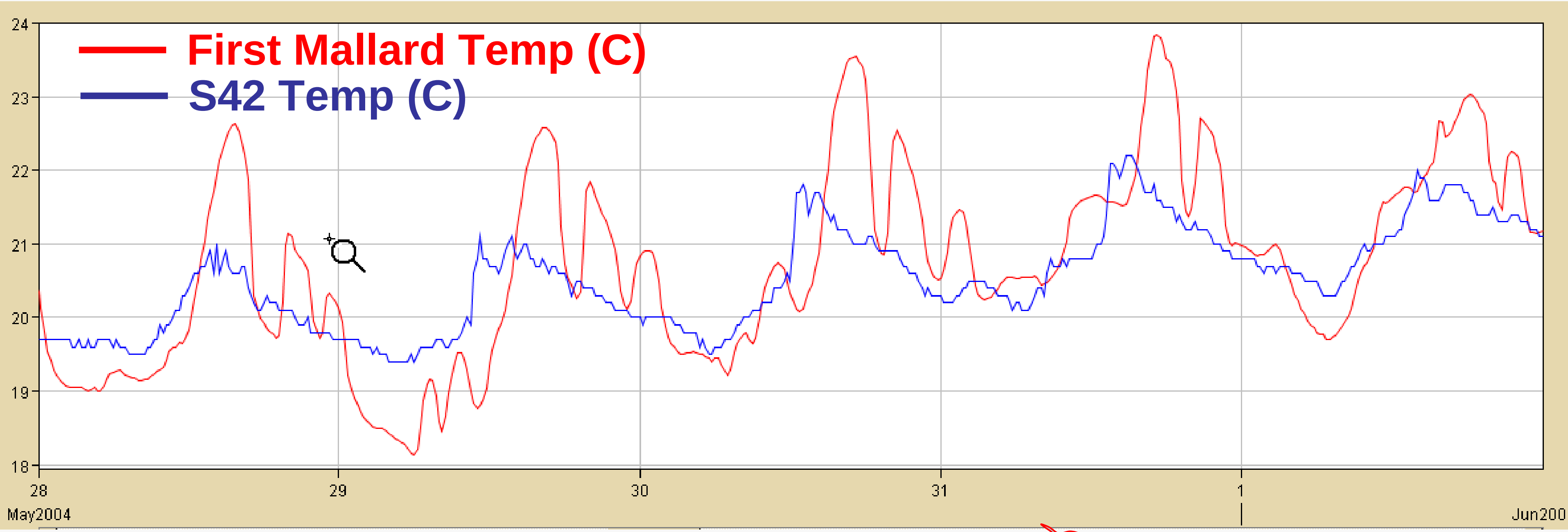


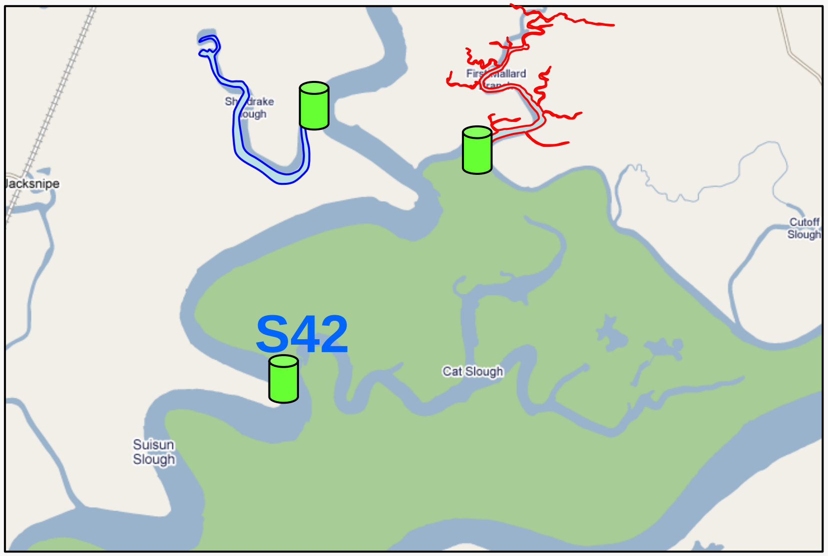
High frequency variability at First Mallard Branch

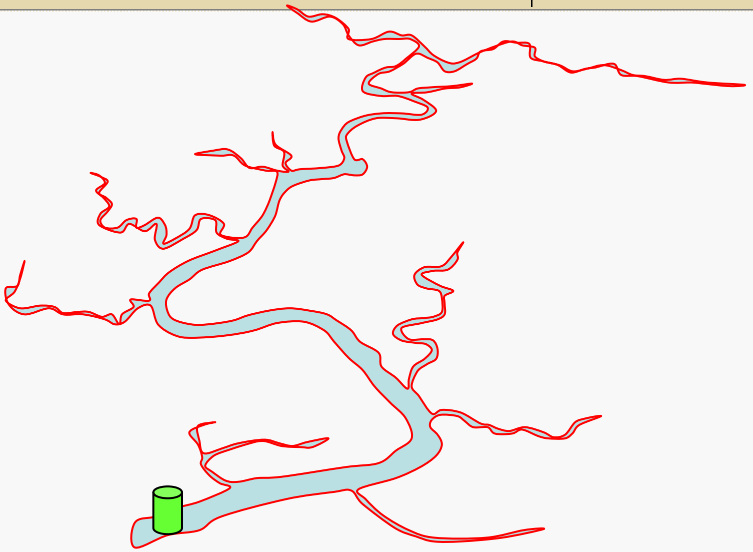




High frequency variability at First Mallard Branch







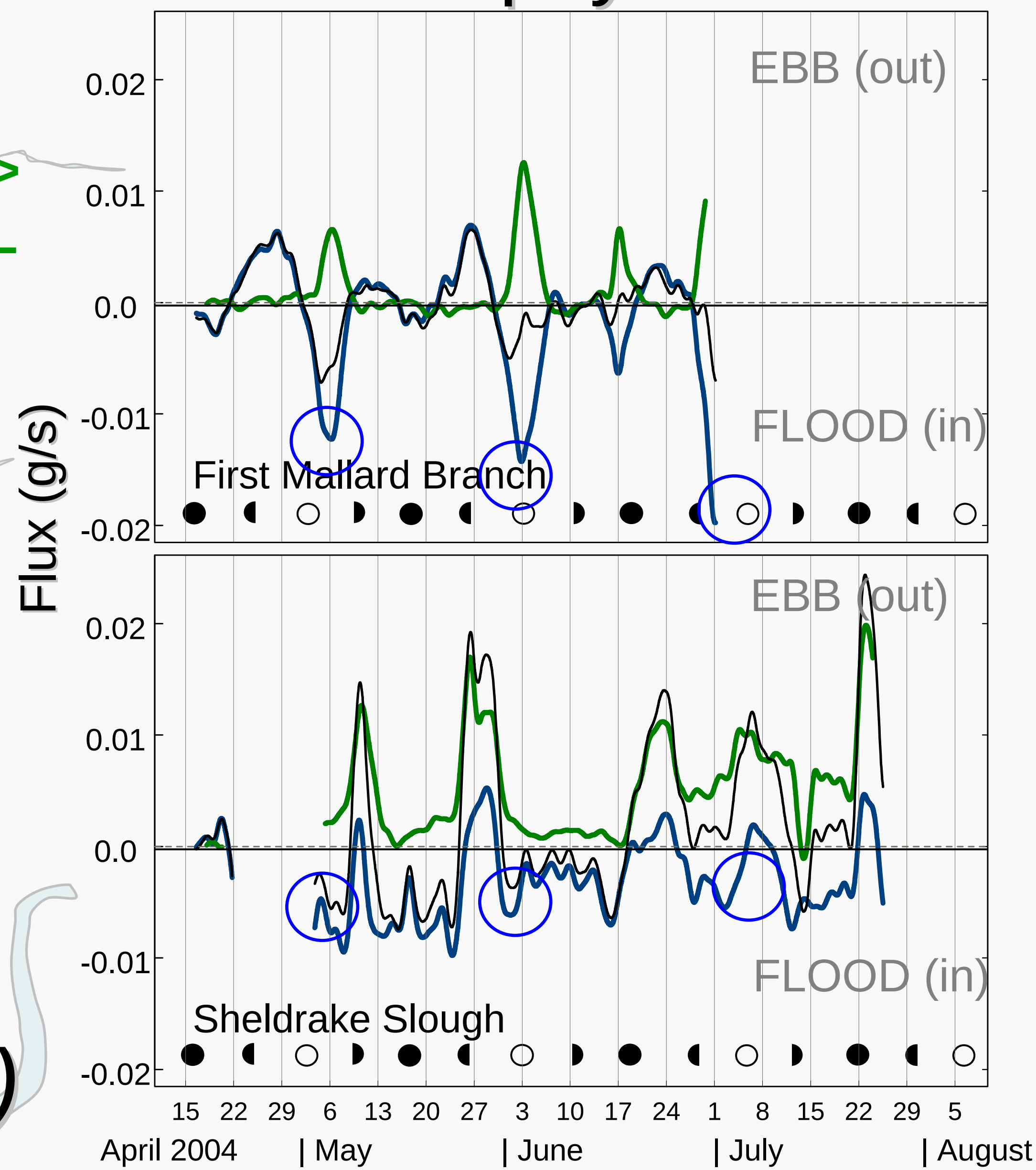
Total Flux = **Advective Flux** (Spring-Neap) + **Dispersive Flux** (Tides)

<Qt*Ct> = <Qt><Ct> + <Q’t*C’t>

Spring Tide
Advective Flux

Note to self: Bergamaschi got .1-.5 gC/m3/day(?) at Brown’s Island

Chlorophyll Flux

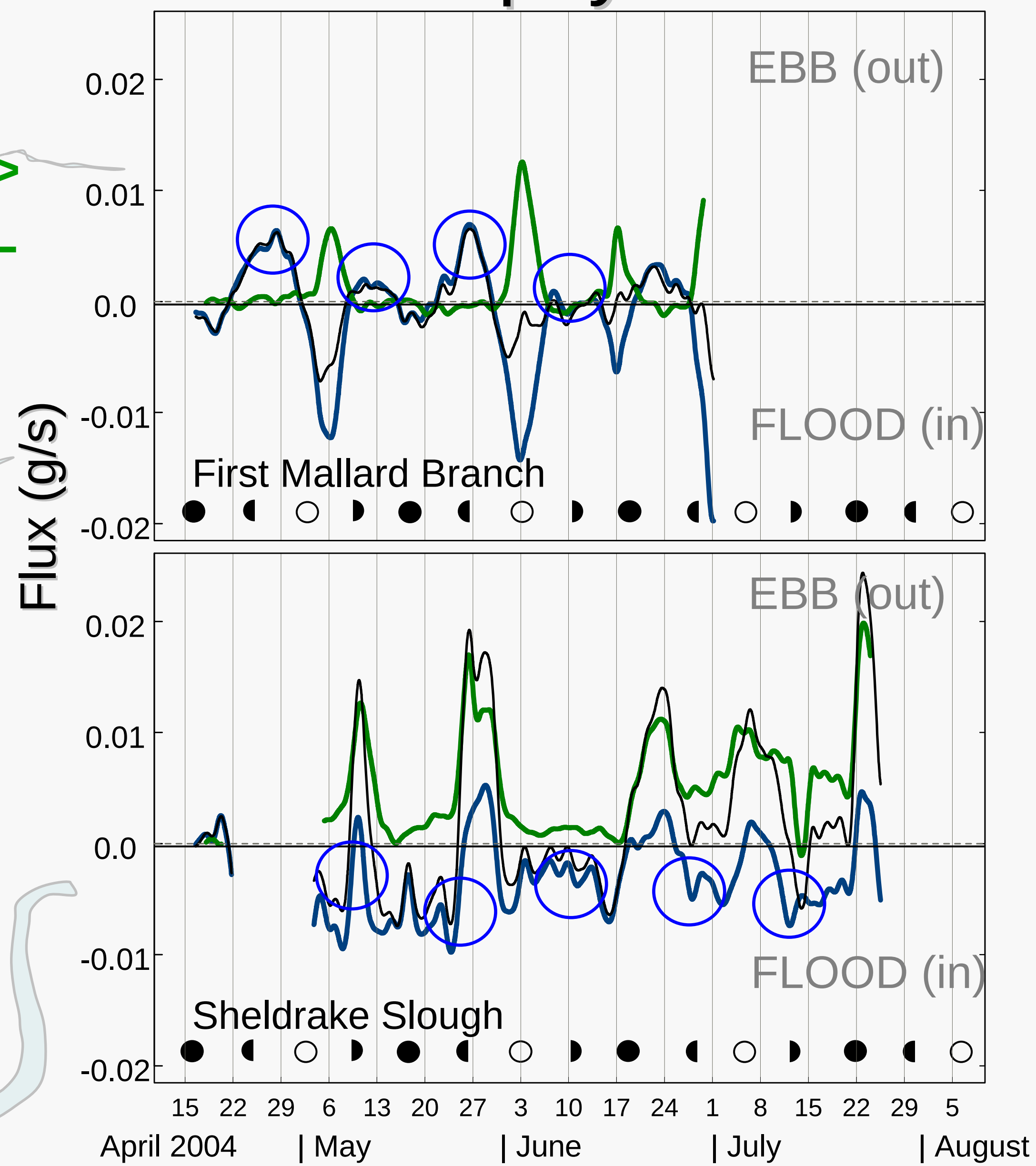


Total Flux = **Advective Flux** (Spring-Neap) + **Dispersive Flux** (Tides)

$$\langle Q_t C_t \rangle = \langle Q_t \rangle \langle C_t \rangle + \langle Q'_t C'_t \rangle$$

Neap Tide
Advective Flux

Chlorophyll Flux

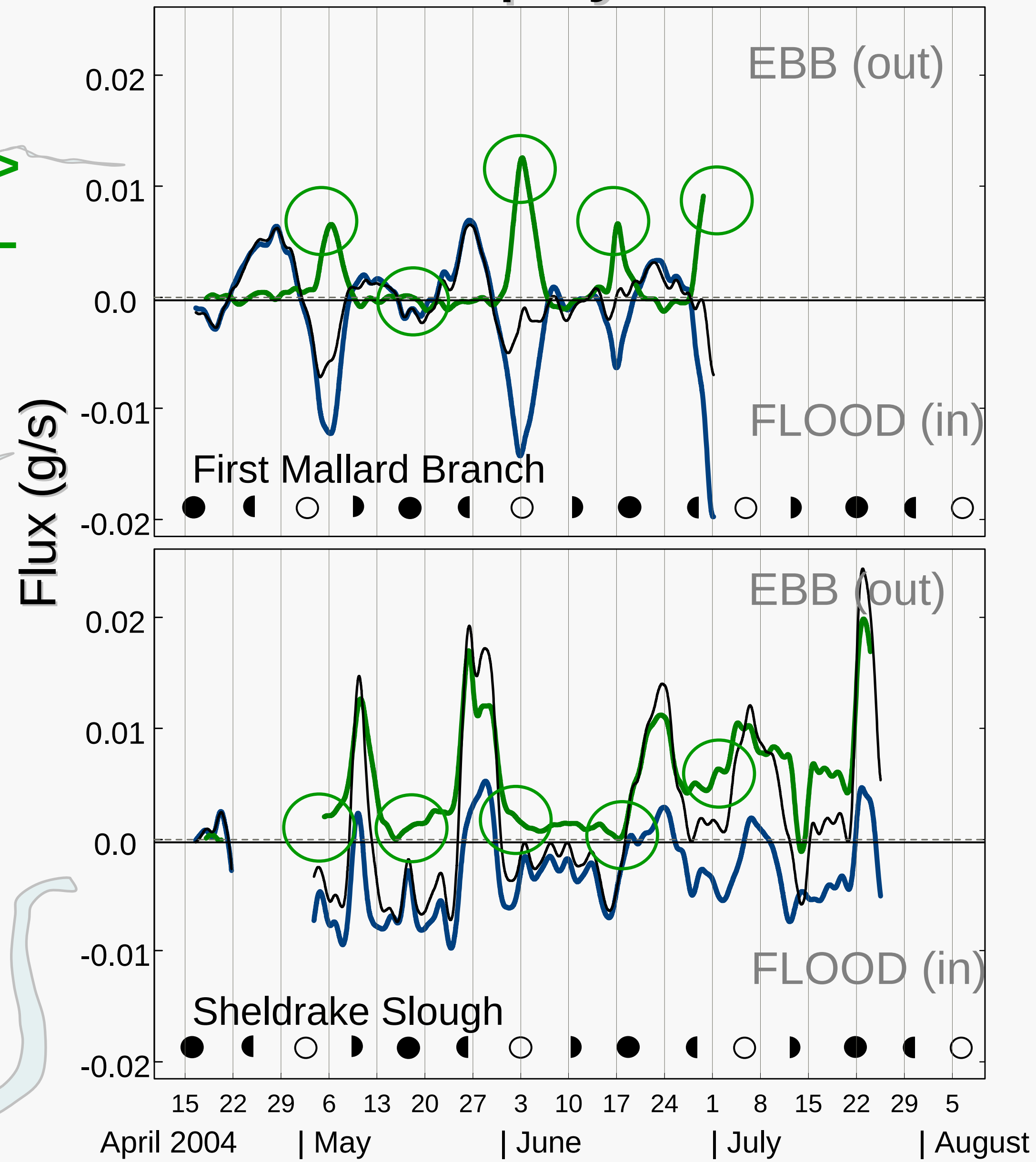


Chlorophyll Flux

Total Flux = **Advective Flux** (Spring-Neap) + **Dispersive Flux** (Tides)

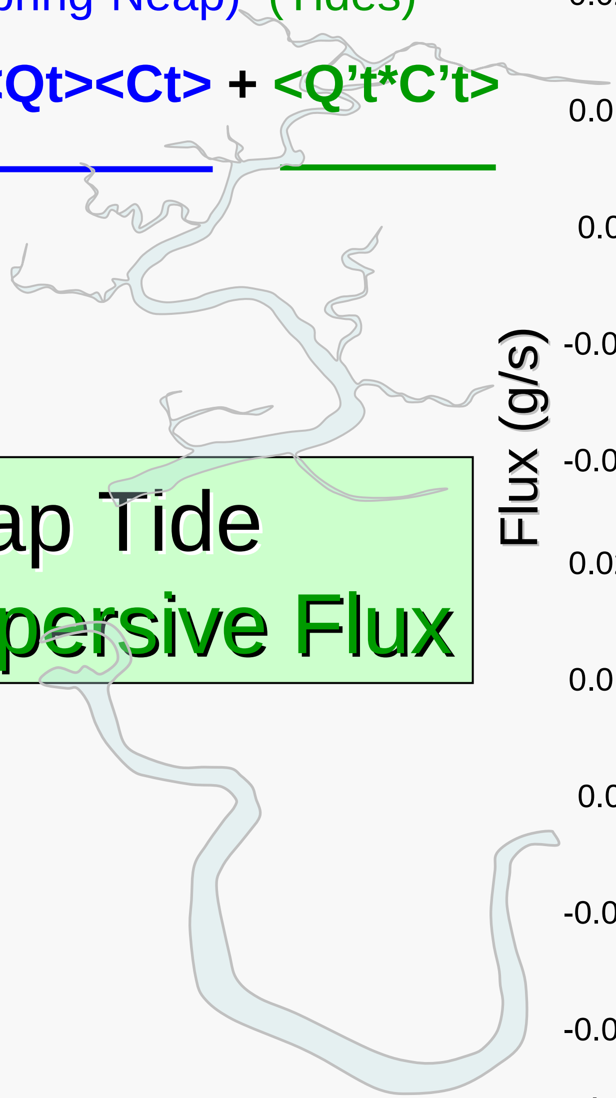
<Qt*Ct> = **<Qt><Ct>** + **<Q't*C't>**

Spring Tide
Dispersive Flux



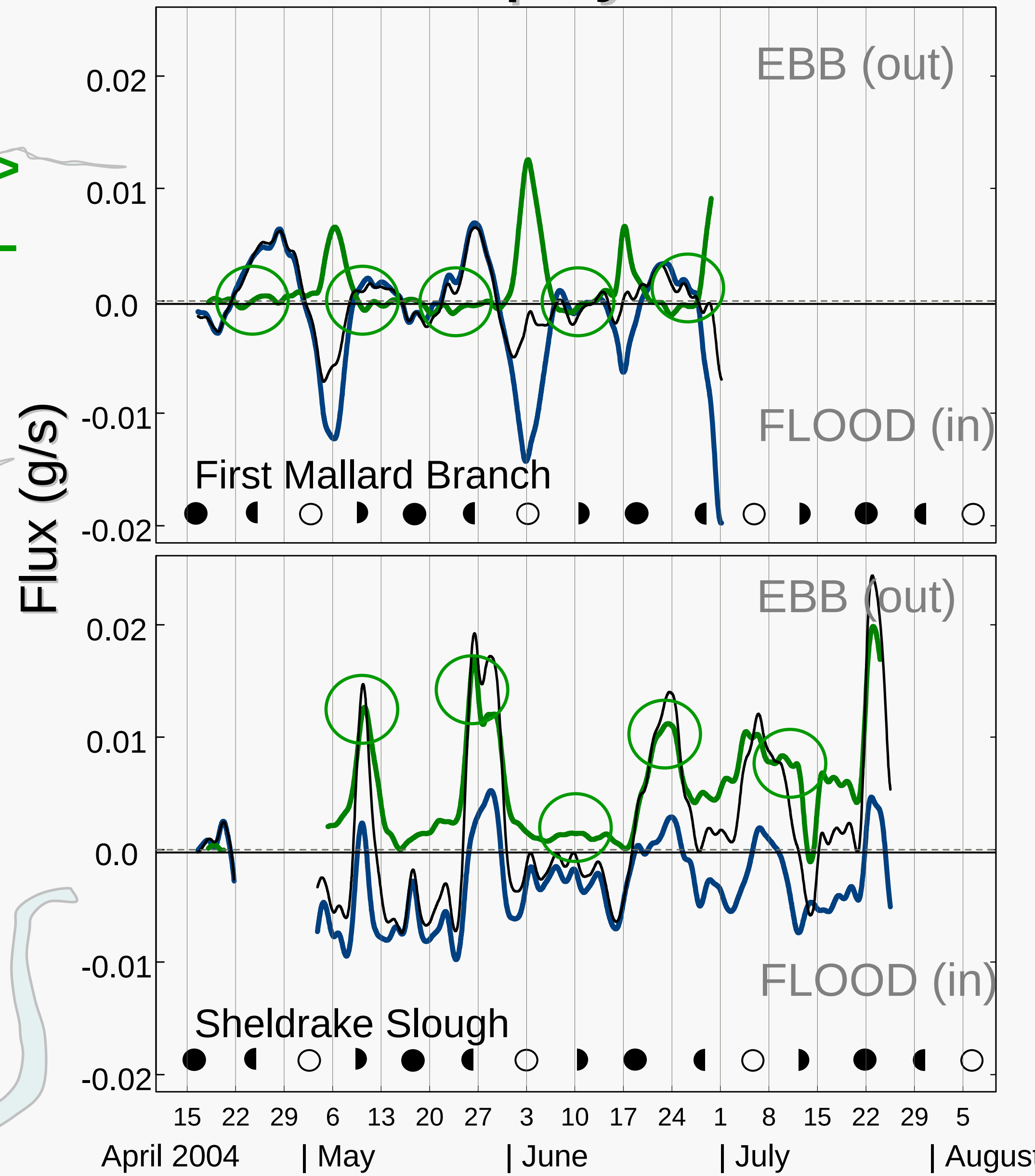
Total Flux = Advective Flux (Spring-Neap) + Dispersive Flux (Tides)

$$\langle Qt*Ct \rangle = \langle Qt \rangle \langle Ct \rangle + \langle Q't*C't \rangle$$



Neap Tide Dispersive Flux

Chlorophyll Flux



Total Flux = Advective Flux (Spring-Neap) + Dispersive Flux (Tides)

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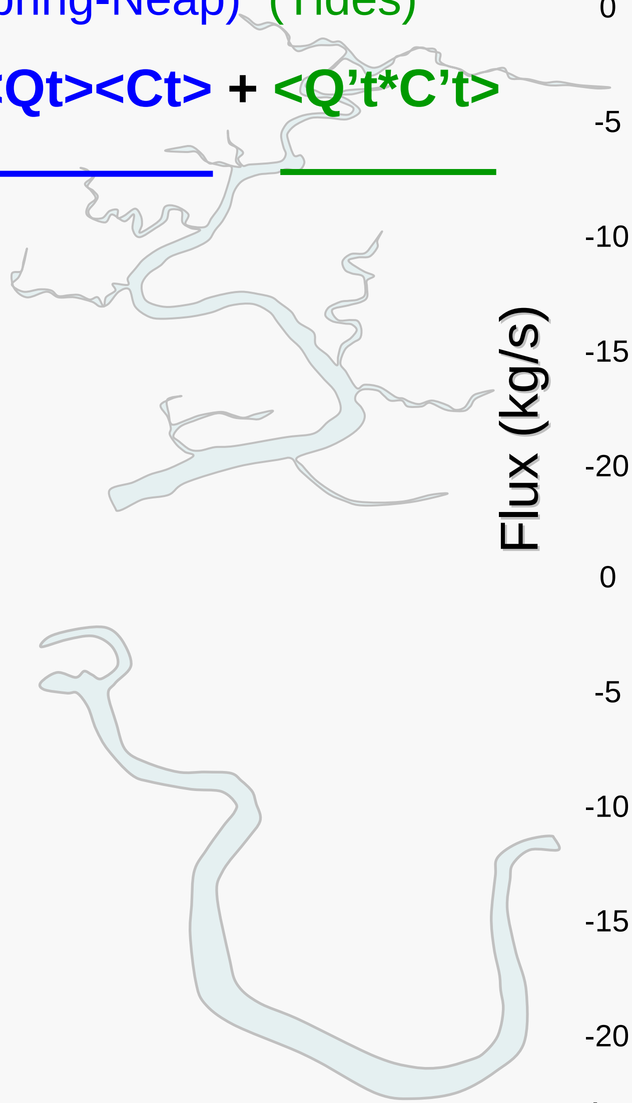
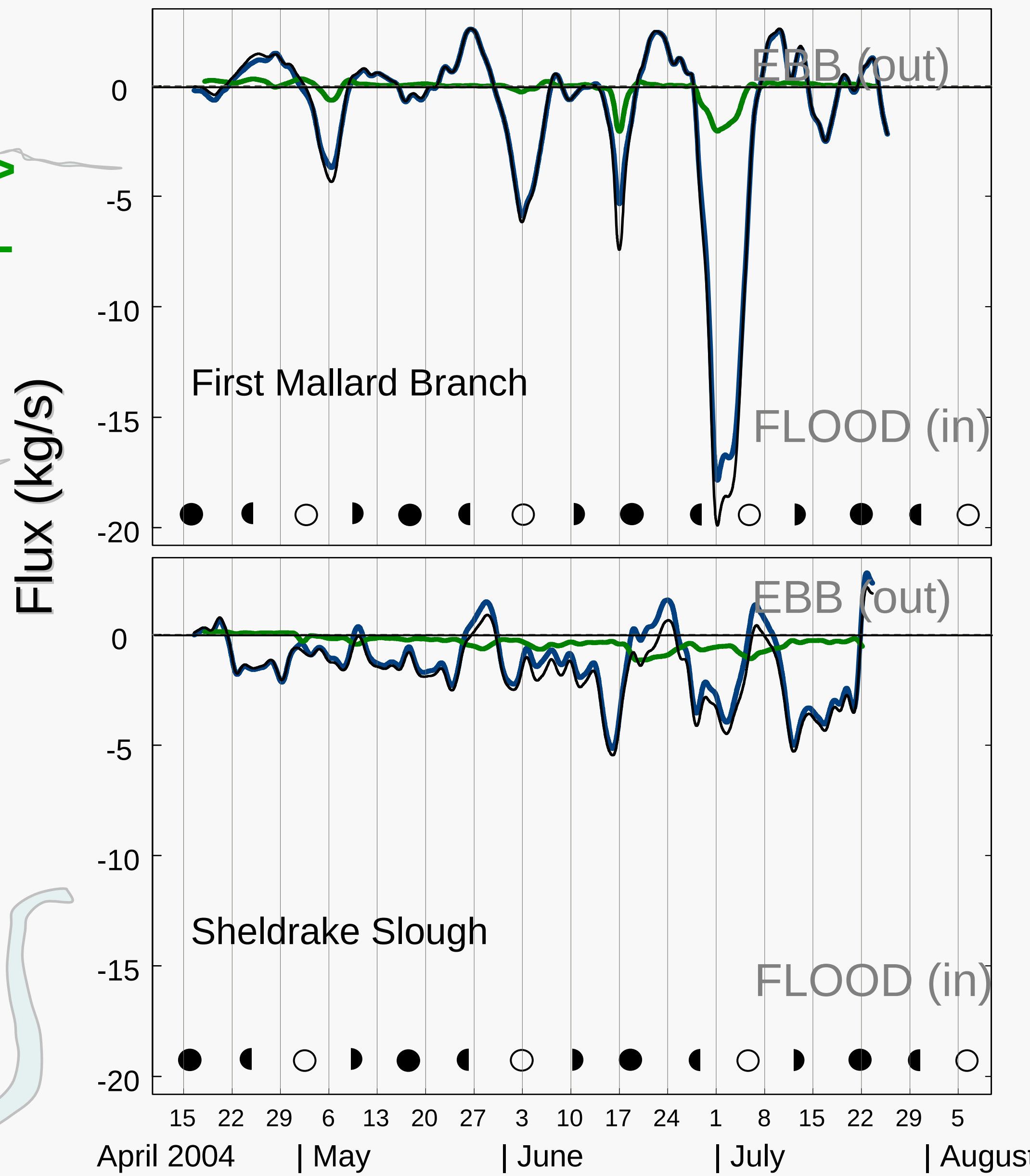


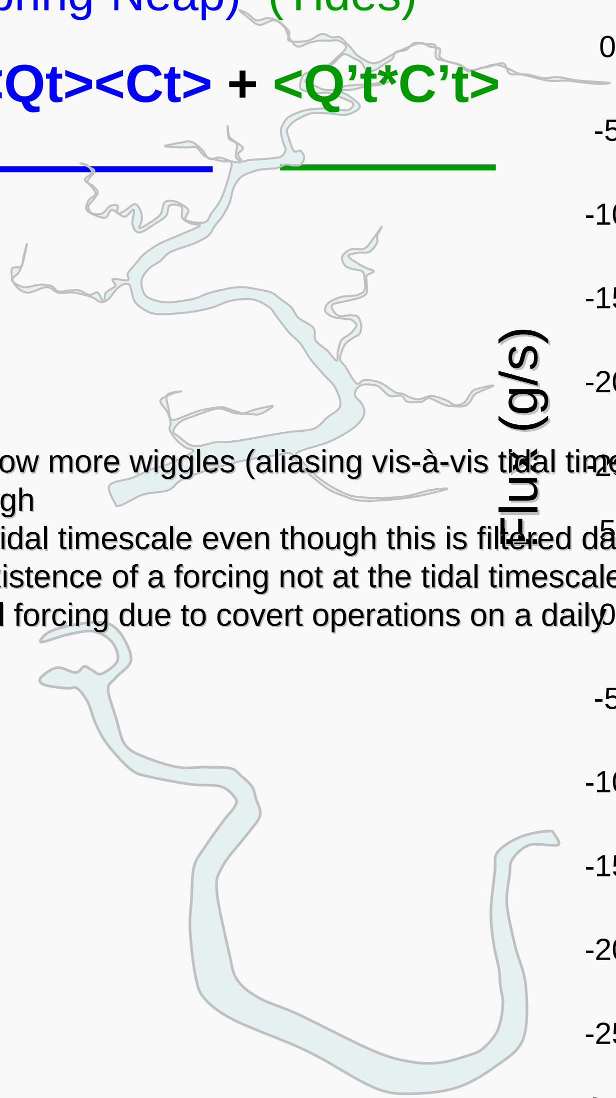
Salt Flux

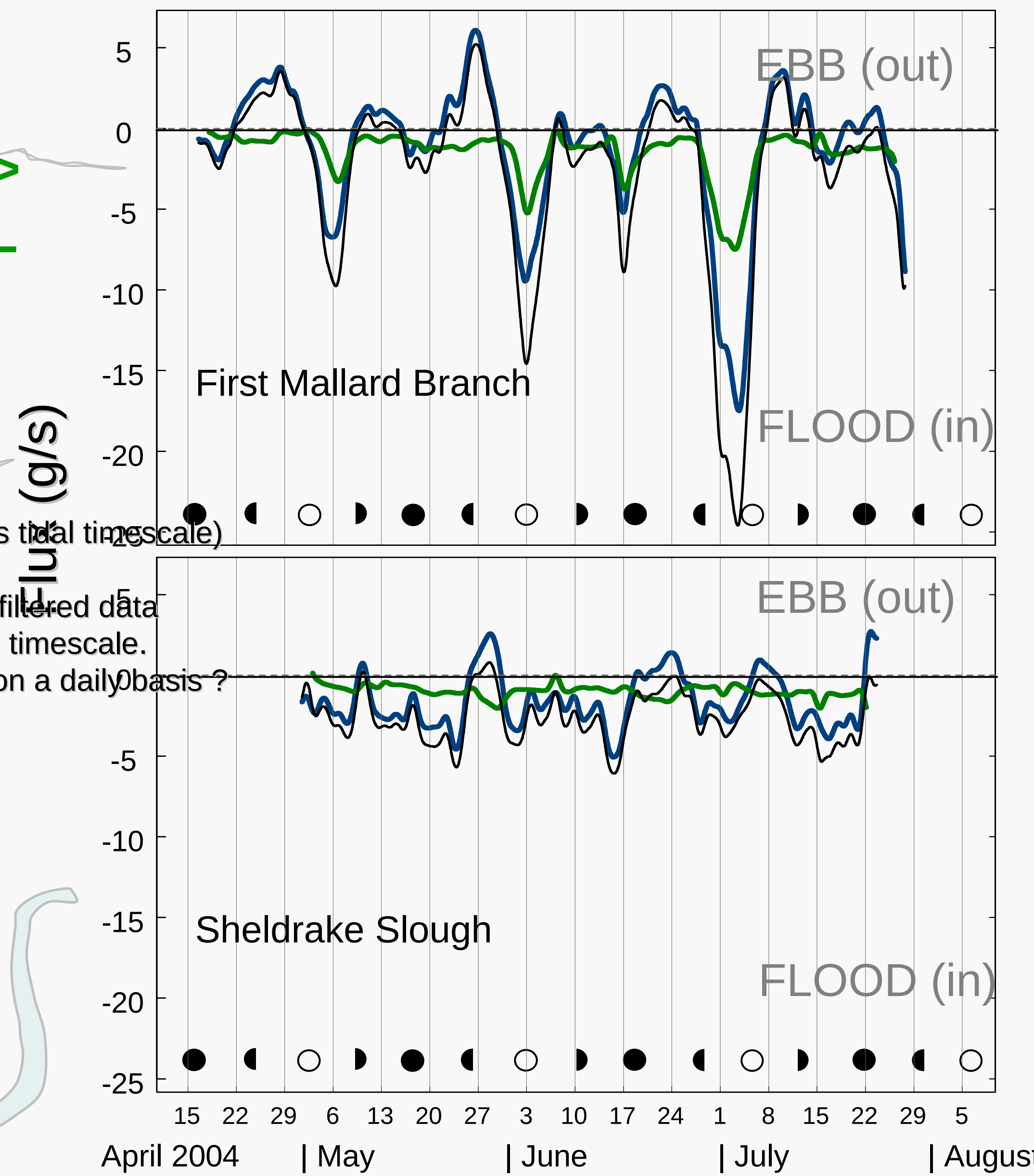


DO Flux

Total Flux = **Advective Flux** (Spring-Neap) + **Dispersive Flux** (Tides)

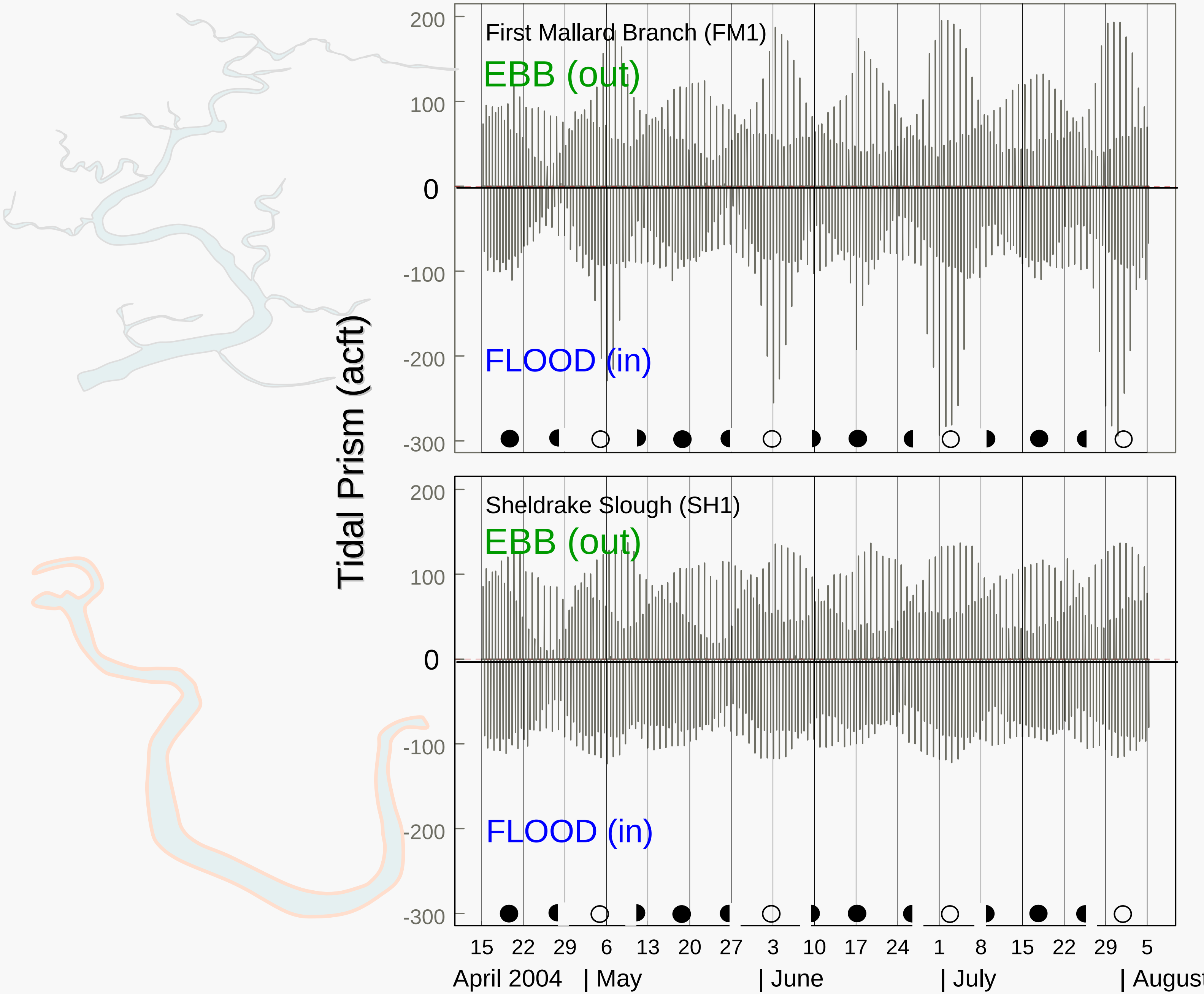
<Qt*Ct> = <Qt><Ct> + <Q't*C't>





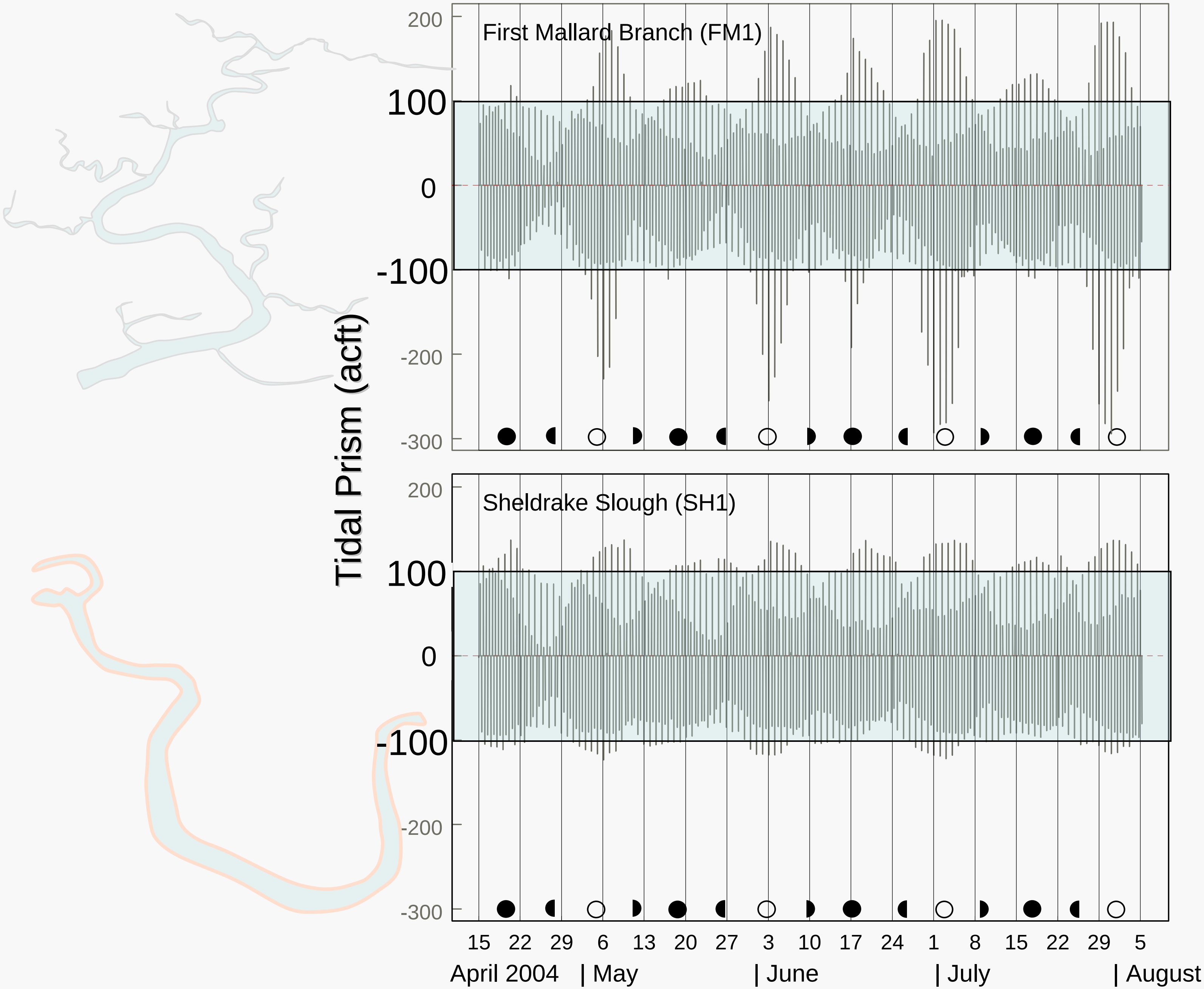
all plots tend to show more wiggles (aliasing vis-à-vis tidal timescale)
in Sheldrake Slough
seemingly on the tidal timescale even though this is filtered data
which suggests existence of a forcing not at the tidal timescale.
could this be a diel forcing due to covert operations on a daily basis ?

Tidal Prism



Tidal Prism (acft)
First Mallard Branch (FM1)
EBB (out)
FLOOD (in)
Sheldrake Slough (SH1)
EBB (out)
FLOOD (in)
200
100
0
-100
-200
-300
15 22 29 6 13 20 27 3 10 17 24 1 8 15 22 29 5
April 2004 | May | June | July | August

Tidal Prism


Tidal Prism (acft)
First Mallard Branch (FM1)
Sheldrake Slough (SH1)
200
100
0
-100
-200
-300
15
22
29
6
13
20
27
3
10
17
24
1
8
15
22
29
5
April 2004
| May
| June
| July
| August

Connectivity lost:
Tidal creeks systems are now “Lakes”

There are many others...